Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2662468 C 2013/02/19

(11)(21) **2 662 468**

(12) **BREVET CANADIEN
CANADIAN PATENT**

(13) **C**

(22) Date de dépôt/Filing Date: 2009/04/14
(41) Mise à la disp. pub./Open to Public Insp.: 2009/10/30
(45) Date de délivrance/Issue Date: 2013/02/19
(30) Priorité/Priority: 2008/04/30 (US12/112,714)

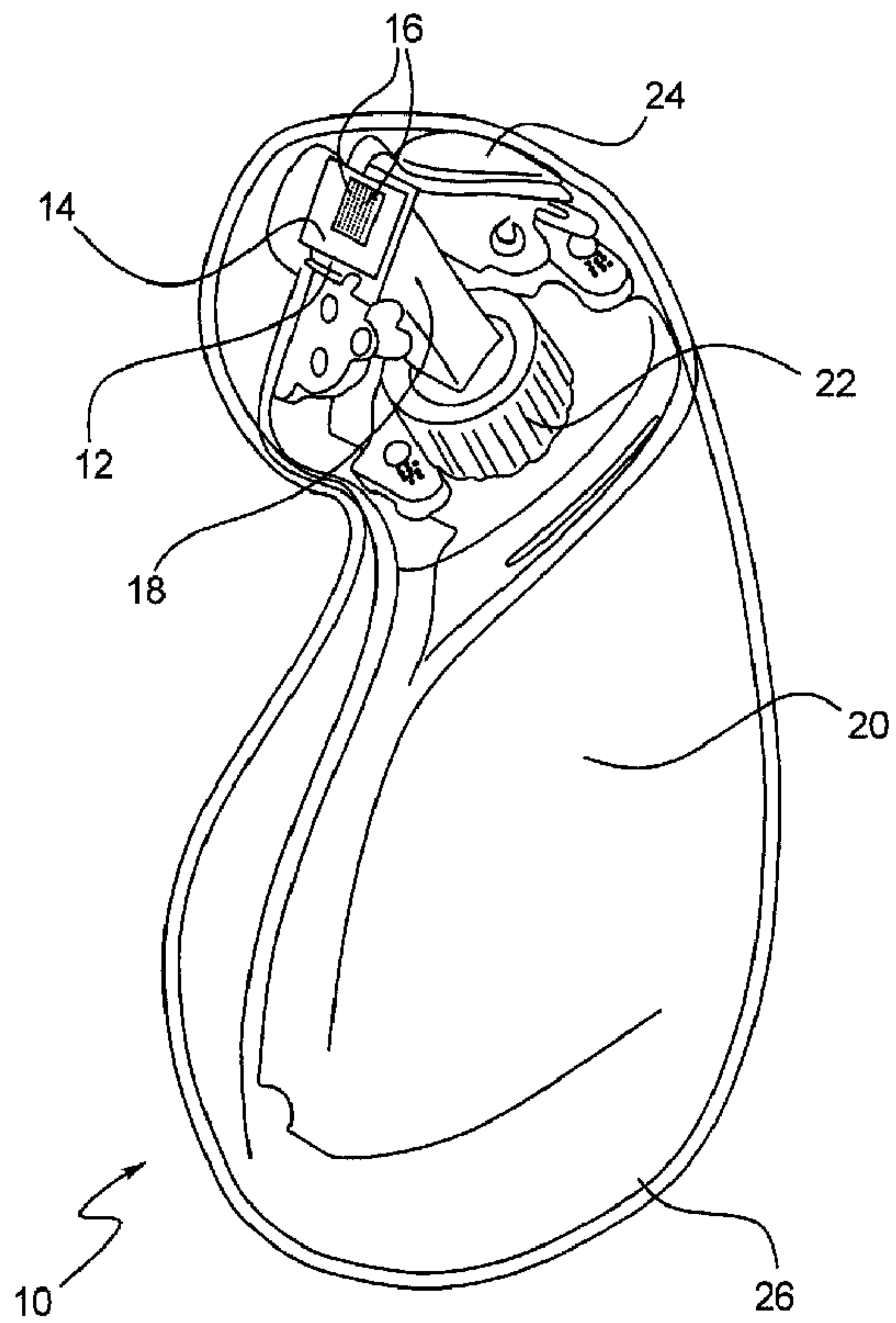
(51) Cl.Int./Int.Cl. *B05B 17/00* (2006.01), *B05B 3/00* (2006.01)

(72) Inventeurs/Inventors:
VALPEY, RICHARD S., III, US;
GU, WENLU, US;
HELF, THOMAS A., US;
BLANDINO, THOMAS P., US

(73) Propriétaire/Owner:
S. C. JOHNSON & SON, INC., US

(74) Agent: BERESKIN & PARR LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : BRUMISATEUR A VOLUME ELEVE POUR PRODUITS PULVERISATEURS GENERAUX DES CONSOMMATEURS
(54) Title: HIGH VOLUME ATOMIZER FOR COMMON CONSUMER SPRAY PRODUCTS



(57) Abrégé/Abstract:
A high volume piezoelectric atomizer for use with common consumer spray products is disclosed. The piezoelectric atomizer may include an actuator, a substrate and a supply of a liquid product to be dispensed. The substrate may include a plurality of tapered

(57) Abrégé(suite)/Abstract(continued):
perforations in direct contact with the supply of a liquid product. A control circuit vibrates the actuator, substrate and its tapered perforations against the supply at velocities of at least 500mm/s. Droplets are dispensed at a delivery rate of approximately 0.2 g/s resulting in plumes of at least 2 feet in length resulting in a Valpey factor of at least 51.0.

ABSTRACT OF THE DISCLOSURE

[0057] A high volume piezoelectric atomizer for use with common consumer spray products is disclosed. The piezoelectric atomizer may include an actuator, a substrate and a supply of a liquid product to be dispensed. The substrate may include a plurality of tapered perforations in direct contact with the supply of a liquid product. A control circuit vibrates the actuator, substrate and its tapered perforations against the supply at velocities of at least 500mm/s. Droplets are dispensed at a delivery rate of approximately 0.2 g/s resulting in plumes of at least 2 feet in length resulting in a Valpey factor of at least 51.0.

HIGH VOLUME ATOMIZER FOR COMMON CONSUMER SPRAY PRODUCTS

FIELD OF THE DISCLOSURE

[0001] The present disclosure generally relates to atomizers for consumer spray products, and more particularly, relates to high volume atomizers which vibrate a perforated substrate in contact with a liquid product supply to dispense the liquid product.

BACKGROUND OF THE DISCLOSURE

[0002] Dispensers for releasing liquid products into the ambient air are well known in the art. These devices may deodorize, humidify, disinfect, emit a fragrance, deliver a medical or cosmetic spray, or distribute toxins into the air to kill and or repel unwanted pests, such as insects. Consequently, each application may require a different type of spray or spray property. For instance, some applications may require smaller droplets with a shorter plume length while others may require larger droplets with a longer plume length. Similar considerations may be made with respect to other attributes such as spray orientation, direction, discharge rate, or the like. Therefore, continuous efforts are directed toward new techniques of dispensing liquid products that may adapt to any and all spray requirements.

[0003] Several techniques have been employed to dispense liquid products into the air. One of the more common dispensers includes aerosol dispensers which release pressurized liquid products from gas-filled containers. Common alternatives to aerosol dispensers include atomizers which reduce a liquid product into tiny droplets and or particles to be released into the air as a fine spray. While the dispensers noted above may be useful in releasing liquid products into the ambient air, they have their drawbacks.

[0004] Aerosol dispensers have been commonly used to dispense liquid products and are well known in the art. Moreover, aerosol dispensers provide a low cost method of dispensing liquid products in any orientation and direction. In an aerosol dispenser, the liquid product to be dispensed is typically mixed in a solvent and a propellant. The propellant provides a force to expel the liquid when a user actuates the aerosol container. The two main types of propellants used in aerosol containers today are liquefied propellant gases (LPGs), such as hydrocarbon or hydrofluorocarbon (HFC) gas, and compressed gas propellants, such as compressed carbon dioxide or nitrogen gas. To a lesser extent, chlorofluorocarbon propellants (CFCs) are also used.

[0005] Propellants that use LPGs share several disadvantageous traits. While the use of CFCs is being phased out due to the harmful effects of CFCs on the environment, many aerosol dispensers still use hydrocarbon propellants. Hydrocarbon propellants contain Volatile Organic Compounds (VOCs) which may have detrimental effects on the environment. The content of VOCs in aerosol dispensers is an unwanted byproduct and is consequently regulated by various federal and state regulatory agencies, such as the Environmental Protection Agency (EPA) and California Air Resource Board (CARB).

[0006] Compressed gas propellants also possess disadvantages. Dispensers that use compressed gas propellants exhibit spray attributes that are inconsistent throughout the life of the dispenser. Specifically, their spray performance relies solely on pressure provided by the gas remaining in a container. As the gas is depleted, the spray properties of various dispensers have shown an increase in droplet size and or shorter plume lengths due to the decrease in propellant pressure. In many cases, the lack of propellant pressure leaves excessive amounts of the unused liquid product in the container.

[0007] The concept of atomizers that dispense liquids into the ambient air is also well known in the art. In general these devices supply the liquid product to a vibrating perforated plate which, due to its vibrations, consistently breaks up the liquid into fine droplets and ejects them in the form of a mist or a cloud. As the droplets travel, the liquid evaporates from the droplets and disperses into the atmosphere.

[0008] One disadvantage to atomizers pertains to the inability to spray in any direction and or orientation. Many of the atomizers do not allow transport of a liquid to the vibrating plate for atomization unless the device is upright. For instance, the capillary in a capillary-based atomizer may not be in fluid communication with the liquid product unless it is situated in the upright position. Additionally, many atomizers are not substantially sealed to prevent leaks or spills when the device is not upright.

[0009] Additional drawbacks relate to relatively large discharged particles, low discharge rates and short spray lengths. Dispensing large particles creates situations in which the droplets are too large to effectively evaporate into the ambient air. Subsequently, the droplets may eventually settle on surrounding surfaces to cause more problems than it attempts to solve. Low discharge rates and short spray lengths further limit the atomizer to only certain products and applications. For instance, an atomizer would not be able to spray a fragrance high enough to reach the center of a large room.

[0010] Nonetheless, a few advances have shown an atomizer to release smaller droplets of approximately 30 microns. While the droplet size is consistently smaller, the atomizer discharges at rates of only microliters per hour and ejects plume of less than one foot in length. Other advances have shown an atomizer outputting at increased rates of microliters per second and extending plumes to 15 centimeters. However, the reach of these sprays are still relatively short and the atomizers are still unable to spray in any direction and or orientation.

[0011] Therefore, multiple needs exist for an improved atomizer for common consumer products that is capable of spraying in any orientation, increases plume lengths, increases the delivery rate, and does not release harmful pollutants into the environment. Additional needs exist for improved atomizing techniques that may be easily adapted for use with a wide variety of applications.

SUMMARY OF THE DISCLOSURE

[0012] In accordance with one aspect of the disclosure, a high volume atomizer for dispensing a liquid product is provided which comprises an actuator; a substrate to which the actuator is operatively associated, the substrate comprising a plurality of perforations; a supply of the liquid product in contact with the perforations; and a control circuit in electrical communication with the actuator; wherein the actuator is capable of vibrating the substrate at a velocity no less than 500 mm/s and is selected from the group consisting of a piezoelectric ceramic, a piezoelectric crystal, a flextensional transducer, an oscillating magnetic couple, a high speed motor, and a servo motor.

[0013] In accordance with another aspect of the disclosure, a high volume piezoelectric atomizer for dispensing a liquid product is provided which comprises a first piezoelectric actuator; a substrate to which the piezoelectric actuator is operatively associated, the substrate comprising a plurality of perforations; a supply of the liquid product in contact with the perforations; and a control circuit in electrical communication with the piezoelectric actuator.

[0014] In accordance with another aspect of the disclosure, a high volume piezoelectric atomizer for dispensing a liquid product is provided which comprises a substantially sealed liquid chamber; an electronics chamber; a piezoelectric actuator; a substrate comprising a plurality of tapered perforations; a supply of the liquid product in contact with the tapered perforations; and a control circuit disposed within the electronics chamber, the control circuit in electrical communication with the piezoelectric actuator.

[0015] In accordance with another aspect of the disclosure, a high volume atomizer for dispensing a liquid product having a Valpey factor of at least 51.0 is provided which comprises an actuator; a substrate to which the actuator is operatively associated, the substrate comprising a plurality of perforations; a supply of the liquid product in contact with the perforations; and a control circuit in electrical communication with the actuator.

[0016] These and other aspects of this disclosure will become more readily apparent upon reading the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 is a perspective view of an exemplary high volume piezoelectric atomizer constructed in accordance with the teachings of the disclosure;

[0018] FIG. 2A is a schematic diagram of an exemplary atomizer;

[0019] FIG. 2B is a schematic diagram of an exemplary control circuit;

[0020] FIG. 3A is a perspective view of an atomizer with one actuator;

[0021] FIG. 3B is a perspective view of an atomizer with two actuators;

[0022] FIG. 4A-4G are magnified cross-sectional views of generally tapered perforations disposed within a substrate;

[0023] FIG. 5A is a top plan view of an exemplary actuator plate arrangement;

[0024] FIG. 5B is a side view of the actuator plate arrangement of FIG. 5A;

[0025] FIG. 5C is a schematic diagram used to construct the actuator plate arrangement of FIGS. 5A and 5B;

[0026] FIG. 6A is a table providing specifications for two exemplary plates A and B;

[0027] FIG. 6B is a schematic diagram of a control circuit for use with the first plate A of FIG. 6A;

[0028] FIG. 6C is a schematic diagram of a control circuit for use with the second plate B of FIG. 6A; and

[0029] FIG. 6D is a table providing the spray properties of the two plates A and B of FIG. 6A.

[0030] While the present disclosure is susceptible to various modifications and alternative constructions, certain illustrative embodiments thereof have been shown in the drawings and will be described below in detail. It should be understood, however, that there is no intention to limit the present invention to the specific forms disclosed.

DETAILED DESCRIPTION

[0031] Referring now to the drawings and with particular reference to FIG. 1, an exemplary high volume atomizer for use with air fresheners, deodorants, insecticides, repellents, cleaners, medicinal substance, aromatherapy substance, disinfectant, sanitizer, or other common consumer spray products, is referred to as reference number 10. It is understood that the teachings of the disclosure can be used to construct atomizers and related dispensers other than those specifically disclosed below. One of ordinary skill in the art will readily understand that the following are exemplary embodiments.

[0032] As shown in FIG. 1, an exemplary high volume piezoelectric atomizer 10 for common consumer spray products may include an actuator 12 and a substrate 14 to which the actuator 12 may be coupled. The actuator 12 may be a piezoelectric ceramic actuator, or may be a piezoelectric crystal, a flextensional transducer, an oscillating magnetic couple, a high speed motor, a servo motor, or any other device that may be capable of vibrating the substrate 14 at relatively high frequencies and velocities. Additionally, the substrate 14 may employ an element such as a plate, a cantilever, a diving board, or the like, that may be elliptical, rectangular, cylindrical, or in any other shape or form. The substrate 14 of FIG. 1 may further include a plurality of generally tapered perforations 16, similar to those described in U.S. Pat. Nos. 5,164,740, 6,629,646 and 6,926,208 to Ivri, which may be in contact with a liquid product supply 18, such as a wick.

[0033] Wicks, as described herein, have a plurality of non-capillary fibers and are adapted to the polarity and or non-polarity of a particular liquid product. Such wick compositions serve to promote the ability to spray in any orientation and or direction, and to minimize inconsistencies caused by gravity. More specifically, gravity may significantly impede fluid flow if a wick is longer than a few millimeters and transports fluid against the force of gravity. In order to overcome gravity at delivery rates exceeding microliters per minute, the composition and properties of a wick may be modified. Some important properties affecting the performance of a wick may include the pore size, pore volume and hydrophilicity. Of these properties, hydrophilicity has the greatest impact on the performance of a wick. Furthermore, the hydrophilicity of a wick composition may be one that is compatible with the polarity of a particular liquid product to be dispensed.

[0034] The majority of liquid products that may be used with the embodiments disclosed herein may include aqueous mixtures of actives and other ingredients, for example, air fresheners, insecticides, repellents, cleaners, or the like. For such liquids, a typical hydrophilic wick, for example polyester, may be used for optimal compatibility and uninterrupted performance. In contrast, cotton may be too hydrophilic while polyethylene may be too hydrophobic. Alternatively, for applications involving non-polar liquid products, a hydrophobic wick such as polyethylene may provide better performance than cotton, nylon, polyester, or the like.

[0035] Still referring to FIG. 1, the high volume piezoelectric atomizer 10 may further include a liquid chamber 20 and a cap 22 for containing a liquid product. The wick 18 may transport a liquid product from the liquid chamber 20 to the tapered perforations 16 to be atomized. The liquid chamber 20 may be substantially sealed by the wick 18 and the cap 22 to prevent leaks and spills. Additionally, the cap 22 may include a gasket to further seal the liquid chamber 20 and to promote atomization of the liquid product in any direction and or orientation. Alternatively, the liquid chamber 20 and or cap 22 may be removable to allow for refills.

[0036] As shown in the particular embodiment of FIG. 1, the atomizer 10 may further include a trigger 24 and an electronics chamber 26 comprising a control circuit disposed therein. The electronics chamber 26 may provide electrical communication between the control circuit, the piezoelectric actuator 12 and the trigger 24. Upon engaging the trigger 24, the control circuit may be powered by at least one battery also disposed within the electronics chamber 26. Alternatively, power to the control circuit may be supplied by an external AC or DC source.

[0037] A piezoelectric actuator 12 may include a piezoelectric material that converts mechanical energy into electrical energy, and vice versa. More specifically, providing pulsed electrical current to a piezoelectric actuator 12 may mechanically vibrate the actuator 12 and its associated substrate 14. A control circuit for providing such current may be provided in electrical communication with the piezoelectric actuator 12 via wires or other conductors. Upon actuation, the control circuit may vibrate the substrate 14 and its tapered perforations 16 against a liquid product supply or a wick 18 at velocities of 500 mm/s or more. Subsequently, the atomized liquid product may be dispensed from the perforations 16 to provide plumes of approximately 2 feet (610 mm) or more in length.

[0038] Referring now to FIG. 2A, a schematic diagram further illustrates the relationships between the components of an exemplary atomizer 10a. In general, an atomizer 10a may include an actuator 12a, a substrate 14a with perforations 16a coupled to the actuator 12a, a supply of a liquid product 18a in contact with the substrate 14a, and a control circuit 28. Additionally, the atomizer 10a may further include a liquid chamber

20a, a cap 22a, a gasket 23a, a trigger 24a, and an electronics chamber 26a, as indicated in phantom. Upon engaging the trigger 24a, the control circuit 28 may begin vibrating the actuator 12a. Vibrating the actuator 12a may further vibrate the substrate 14a and its perforations 16a against the supply 18a, and atomize a liquid product contained in the liquid chamber 20a.

[0039] Turning to FIG. 2B, a control circuit 28 may include a power supply 30, a voltage converter 32, an oscillator 34 and a feedback circuit 36. The power supply 30 may provide the voltage converter 32 with a DC voltage from an internal or an external source. The converter 32 may convert the voltage provided by the power supply 30 to a level suitable to drive the actuator 12a. Subsequently, the oscillator 34 may pulse the signal to vibrate the actuator 12a. To ensure consistent vibrations, the feedback circuit 36 may sample the vibration frequency and relay the information back to the oscillator 34. Depending on any differences between the ideal and the actual frequencies, the oscillator 34 may adjust the frequency of the signal sent to the actuator 12a.

[0040] Turning now to FIG. 3A, another exemplary high volume piezoelectric atomizer 10b may include a piezoelectric ceramic actuator 12b and a substrate 14b to which the actuator 12b may be coupled. Alternatively, the actuator 12b may include a piezoelectric crystal, a flextensional transducer, an oscillating magnetic couple, a high speed motor, a servo motor, or any other device that may be capable of vibrating the substrate 14b at relatively high frequencies. Additionally, the substrate 14b may employ an element such as a plate, a cantilever, a diving board, or the like, that may be elliptical, rectangular, cylindrical, or of any other shape or form. The substrate 14b of FIG. 3A may further include a plurality of generally tapered perforations 16b which may be in contact with a supply of a liquid product, such as a wick 18b. The wick 18b may transport a liquid product from a container, a reservoir, or the like, toward the tapered perforations 16b to be atomized and dispensed in the general direction indicated by the exit arrow 29.

[0041] Turning to FIG. 3B, yet another exemplary high volume piezoelectric atomizer 10b1 may include two piezoelectric ceramic actuators 12b1, 12b1' and a substrate 14b1 to which the actuators 12b1, 12b1' may be coupled. Alternatively, the actuators 12b1, 12b1' may employ a piezoelectric crystal, a flextensional transducer, an oscillating magnetic couple, a high speed motor, a servo motor, or any other device that may be capable of vibrating the substrate 14b at relatively high frequencies. Additionally, the substrate 14b1 may include a plate, a cantilever, a diving board, or the like, that may be elliptical, rectangular, cylindrical, or of any other shape or form. As with previous embodiments, the substrate 14b1 of FIG. 3B may further include a plurality of generally tapered perforations 16b1 which may be in contact with a supply of a liquid product, such as a wick 18b1. The wick 18b1 may transport a liquid product from a container, a reservoir, or the like, toward the tapered perforations 16b1 to be atomized and dispensed in the general direction indicated by the exit arrow 31.

[0042] Turning to FIG. 4A, a detailed cross-sectional view of an exemplary tapered perforation 16c of another substrate 14c is shown with a wick 18c, or a similar supply of a liquid product. The perforation 16c may be tapered with an angle θ of approximately 20 to 30 degrees, and with an axis N normal to the substrate 14c. Alternatively, as shown in FIG. 4B, the perforation 16c1 may be tapered to form the shape of a bell with an average angle θ. The perforations 16c2, 16c3 of FIGS. 4C and 4D are additional variations that may be tapered to only partially mimic a bell shape and form an average angle θ with the normal axis *N*. Furthermore, the perforations 16c4-6 of FIGS. 4E-4G illustrate other possible variations that may form an average taper angle of θ with the normal axis *N*. As with the perforation 16c of FIG. 4A, each variation of FIGS. 4B-4G may form an average angle θ of approximately 20 to 30 degrees with the axis *N* normal to the substrate 14c.

[0043] Referring back to the particular embodiment of FIG. 4A, the tapered perforation 16c may be configured such that the larger opening of the perforation 16c is in direct contact with the wick 18c, or a similar liquid product supply. During atomization, a liquid product from the wick 18c may enter the perforation 16c through the larger opening. Subsequently, a plurality of droplets D may exit from the smaller opening to form a plume in the direction indicated by the exit arrow 33.

[0044] Turning now to FIGS. 5A-5C, an exemplary actuator plate arrangement 40 is provided. As in previous embodiments, the arrangement 40 may include an actuator 12d and a plate substrate 14d with a plurality of tapered perforations 16d. The actuator 12d may further include wires 42, or other similar conductors, which provide electrical communication to with a control circuit. The diagram of FIG. 5C provides an exemplary schematic that may be used to construct the particular arrangement 40 of FIGS. 5A and 5B. In the center of the arrangement 40, a piezoelectric ceramic 44 may be employed to vibrate the arrangement 40 upon actuation. Alternatively, the piezoelectric ceramic 44 may be substituted with a piezoelectric crystal, a flextensional material or any other means for vibrating the arrangement 40 at relatively high frequencies.

[0045] Still referring to the particular arrangement 40 of FIG. 5C, wires 42, or similar conductors, may be soldered to silver electrodes 46 to provide the arrangement 40 with electric current from a control circuit. The silver electrodes 46 may be coupled to the ceramic 44 using a conducting epoxy 48, or the like. In related embodiments, a thin layer of the silver 46 may be coated onto the ceramic 44 using a silk screen, or a comparable process, and subsequently applying heat to affix the coat. Furthermore, electrodes 46 made from conducting metals other than silver, for example copper, gold, brass, may also be employed.

[0046] The schematic of FIG. 5C further includes a perforated nickel plate 14d coupled to one of the electrodes 46. Alternatively, the nickel plate 14d may be a plate of a different material, a cantilever, a diving board, or any other perforated substrate that may be elliptical, rectangular, cylindrical, or in any other shape or form. The plate 14d may further include a plurality of perforations that are tapered at specific angles for optimal pumping efficiency. Specifically, the perforations may employ a bell shaped taper which forms average taper angles of approximately 20 to 30 degrees with an axis normal to the plate 14d.

[0047] Several factors may contribute to the size of the droplets released by an atomizer. The greatest known contributors may include the size of the perforations in a substrate, or a plate, and the velocity at which the plate vibrates. Moreover, at a constant plate velocity, the droplet size may increase with increasing perforation size, and at a constant perforation size, the droplet size may increase with increasing plate velocity. During the course of experimentation, however, tests provided unexpected results with respect to the particle size of droplets dispensed. It has been determined that a plate with larger perforations may produce a spray with significantly smaller droplets or particles. More specifically, at constant drive voltage and resonant frequency, higher plate velocities in combination with smaller perforations produced larger particles than lower plate velocities and larger perforations.

[0048] Turning to the table of FIG. 6A, the specifications of two different substrates, or plates, A, B that resonate at the same frequency are provided solely to illustrate the aforementioned findings. The plates A, B were constructed with different dimensions and perforation formats. Specifically, the first plate A has smaller dimensions and smaller perforations than those of the second plate B. Such variations in weight, shape, and other similar properties of the plate may cause an arrangement to vibrate at different frequencies and may require separate control circuits. Accordingly, separate control circuits were constructed to vibrate the plates A, B and to compensate for these variations. Smaller perturbations to any part of the arrangement, for example scratches, foreign objects, forces applied by a wick, components of a liquid product, or the like, may also affect performance. However, these smaller perturbations may be overcome by providing the control circuit with feedback means so as to self resonate at specific frequencies.

[0049] Turning now to FIG. 6B, an exemplary control circuit 128a for driving the first actuator 112a for plate A is provided. The control circuit 128a may include a switch 129a, a battery 130a, a boost converter 132a, an oscillator 134a and a feedback circuit 136a. Upon actuation of the switch 129a, the battery 130a supplies a DC voltage to the boost converter 132a. The boost converter 132a converts the input voltage to a higher DC voltage required to drive the actuator 112a. Simultaneously, the oscillator 134a and the feedback circuit 136a determine the optimum operating frequency, or series resonant frequency, by sampling current passing through the actuator 112a. By self resonating and maintaining the series resonant frequency, the control circuit 128a minimizes impedance and allows the arrangement of plate A to be operated at a relatively low voltage. Accordingly, the control circuit 128a is able to consistently drive power to the load and overcome small perturbations.

[0050] Turning now to FIG. 6C, a second exemplary control circuit 128b for driving the second actuator 112b of arrangement of plate B is provided. Similar to the previous circuit 128a, the control circuit 128b may include a switch 129a, a DC power supply 130b, an impedance transformation network 132b, an oscillator 134b and a feedback circuit 136b. Upon actuation of the switch 129a, the power supply 130b feeds DC voltage to the impedance transformation network 132b, which converts the incoming voltage to a higher AC voltage required to drive the actuator 112b. As in the control circuit 128a of FIG. 6B, the oscillator 134b and the feedback circuit 136b work together to vibrate the plate arrangement B more efficiently. Specifically, the oscillator 134b and the feedback circuit 136b determine the series resonant frequency by sampling current passing through the actuator 112b. As a result, the second control circuit 128b is also able to consistently drive power to the load and overcome small perturbations.

[0051] Referring now to FIG. 6D, the resulting properties of sprays from both the plate A and B arrangements are provided. Data corresponding to the particle size of the droplets from each spray were collected on a Malvern® Mastersizer S analyzer. At least five measurements were taken at a distance of 8 inches from each plate A, B, and averaged. The plume distance was estimated subjectively by observers over multiple sprays, and averaged. For this particular experiment, each spray was discharged vertically and the corresponding plume distance was estimated to be the reach of the majority of the spray. Alternative means for measuring plume distance may also be employed. The perforation or plate velocity was measured on a Polytec® PSV-400 Scanning Laser Dopler Vibrometer. Furthermore, the discharge rate was determined through the change in weight of sprays over an interval of 10 seconds. The results presented are averages of three trials.

[0052] The results provided in FIG. 6D emphasize the significance of plate velocity and its ability to vary the size of dispensed droplets. Moreover, despite its larger perforations, droplets produced by the second plate B were significantly smaller than those produced by the first plate A. This is due to the difference in plate velocities between the two arrangements. More specifically, plate A moved much faster than plate B. Although both arrangements were driven at the same resonant frequency, plate A moved faster because of its smaller structure.

[0053] In general, the performance of an atomizer may be measured by examining the properties of its spray. More relevant spray properties may include the size of the droplets, plume length and the rate of discharge. A simplified approach to measuring atomizer performance may combine these traits into one index, for example, a Valpey factor. The Valpey factor may be defined by the equation

$$V_f = 100r_d + 0.1l_p - x_d$$

where r_d is the discharge rate in g/s, l_p is the observed plume length in mm, and x_d is the droplet size in microns. The Valpey factor summarizes atomizer performance, by combining the droplet size, plume length and the discharge rate of an atomizer into one index.

[0054] Based on the foregoing, it can be seen that the present disclosure provides a high volume atomizer with features that improves efficiency and performance. Using the embodiments and the relationships disclosed herein, it is possible to atomize a liquid product into smaller droplets, longer plumes and greater discharge rates. More specifically, an atomizer constructed in accordance with the teachings of the disclosure is capable of providing plume lengths of approximately 2 ft (610 mm) or more and discharge rates of approximately 0.20 g/s or more. Accordingly, the performance of the present disclosure may be summarized to exhibit a Valpey factor of 51.0 or more. Atomizers currently existing in the art exhibit only a fraction of this value.

[0055] Furthermore, the present disclosure is capable of atomizing in any orientation without leaking and without significantly affecting performance. The atomizer includes a liquid chamber with a cap and a gasket, and a novel plate arrangement that is in direct contact with a supply of a liquid product to substantially seal in a liquid product. Moreover, the supply of a liquid product is not provided by capillary action but by using the polarity or non-polarity of a liquid product. The technology allows the device to atomize consistently while it is upright, upside down, sideways, or in any other orientation. This is a significant improvement over atomizers currently existing in the art which may leak, spill or not work at all in such orientations. While a few atomizers may be able to spray in these positions without leaking, their performance is inconsistent and gradually decreases in quality.

[0056] While only certain embodiments have been set forth, alternatives and modifications will be apparent from the above description to those skilled in the art.

These and other alternatives are considered equivalents and within the spirit and scope of this disclosure.

WHAT IS CLAIMED IS:

1. A high volume atomizer for dispensing a liquid product, comprising:

a substrate comprising a plurality of perforations; a supply of the liquid product;

a wick extending from the supply of liquid product and that is in contact with the perforations, the wick being composed entirely of non-capillary fibers;

a first actuator and a second actuator capable of vibrating the substrate at a velocity no less than 500 mm/s and are selected from the group consisting of a piezoelectric ceramic, a piezoelectric crystal, a flextensional transducer, an oscillating magnetic couple, a high speed motor, and a servo motor;

the substrate disposed between the first and second actuators; and

a control circuit in electrical communication with the first actuator.

2. The atomizer of claim 1, wherein the substrate is a cantilever.

3. The atomizer of claim 1, wherein the perforations are tapered at 20 to 30 degree angles with an axis normal to the substrate.

4. The atomizer of claim 1, further comprising a liquid chamber sealed with a cap and a gasket.

5. The atomizer of claim 1, wherein the control circuit comprises a power supply, a voltage converter, an oscillator and a feedback circuit.

6. The atomizer of claim 1, wherein the control circuit is disposed within an electronics chamber.

7. A high volume piezoelectric atomizer for dispensing a liquid product, comprising:

a first piezoelectric actuator; a substrate to which the first piezoelectric actuator is operatively associated, the substrate comprising a plurality of perforations;

a second piezoelectric actuator, the substrate disposed between the first and second piezoelectric actuators;

a supply of the liquid product including a wick in contact with the perforations; and

a control circuit in electrical communication with the first piezoelectric actuator.

8. The piezoelectric atomizer of claim 7, wherein the substrate is a cantilever.

9. The piezoelectric atomizer of claim 7, wherein the perforations are tapered at 20 to 30 degree angles with an axis normal to the substrate.

10. The piezoelectric atomizer of claim 7, further comprising a liquid chamber sealed with a cap and a gasket.

11. The piezoelectric atomizer of claim 7, wherein the wick comprises polyester for use with polar liquid products.

12. The piezoelectric atomizer of claim 7, wherein the wick comprises polyethylene for use with non-polar liquid products.

13. The piezoelectric atomizer of claim 7, wherein the control circuit comprises a power supply, a voltage converter, an oscillator and a feedback circuit.

14. The piezoelectric atomizer of claim 7, wherein the control circuit is disposed within an electronics chamber.

15. The piezoelectric atomizer of claim 7, wherein the control circuit provides a substrate velocity greater than 500 mm/s.

16. A high volume piezoelectric atomizer for dispensing a liquid product, comprising:

a sealed liquid chamber; an electronics chamber;

a first piezoelectric actuator;

a substrate comprising a plurality of tapered perforations;

a second piezoelectric actuator, the substrate being disposed between the first and second piezoelectric actuators;

a supply of the liquid product including a wick in contact with the tapered perforations; and

a control circuit disposed within the electronics chamber, the control circuit in electrical communication with the piezoelectric actuators.

17. The piezoelectric atomizer of claim 16, wherein the liquid chamber further comprises a cap and a gasket.

18. The piezoelectric atomizer of claim 16, wherein the substrate is a cantilever.

19. The piezoelectric atomizer of claim 16, wherein the perforations are tapered at 20 to 30 degree angles with an axis normal to the substrate.

20. The piezoelectric atomizer of claim 16, wherein the control circuit comprises a power supply, a voltage converter, an oscillator and a feedback circuit.

21. The piezoelectric atomizer of claim 16, wherein the control circuit provides a substrate velocity greater than 500 mm/s.

22. A high volume atomizer for dispensing a liquid product, comprising:

an actuator;

a substrate to which the actuator is operatively associated, the substrate comprising a plurality of perforations;

a supply of the liquid product including a wick in contact with the perforations; and

a control circuit in electrical communication with the actuator, the atomizer having a Valpey factor of at least 51.0.

23. The atomizer of claim 22, wherein the actuator comprises a piezoelectric material.

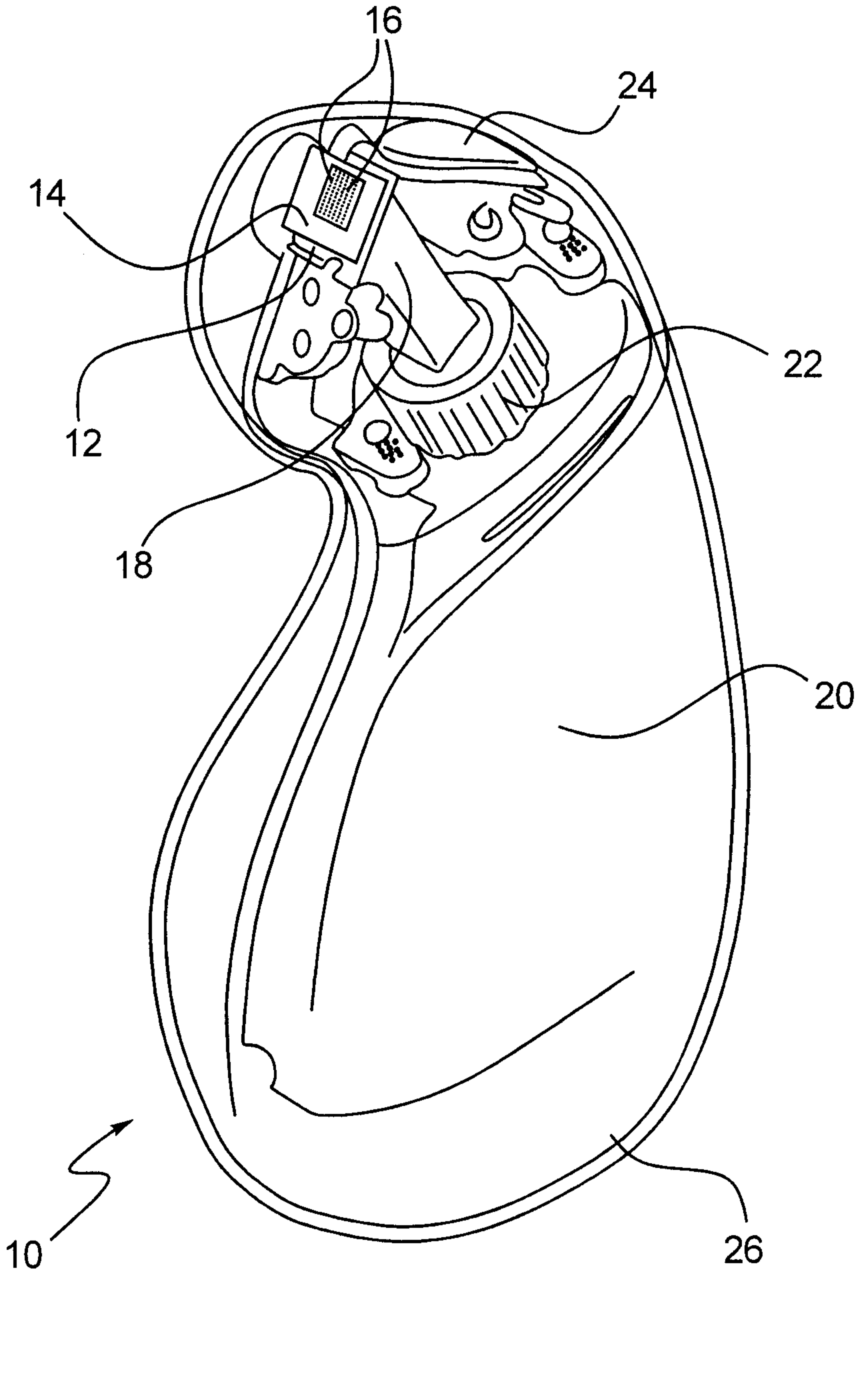
24. The atomizer of claim 22, wherein the perforations are tapered at 20 to 30 degree angles with an axis normal to the substrate.

25. The atomizer of claim 22, further comprising a liquid chamber sealed with a cap and a gasket.

26. The atomizer of claim 22, wherein the control circuit comprises a power supply, a voltage converter, an oscillator and a feedback circuit.

27. The atomizer of claim 22, wherein the control circuit is disposed within an electronics chamber.

FIG. 1



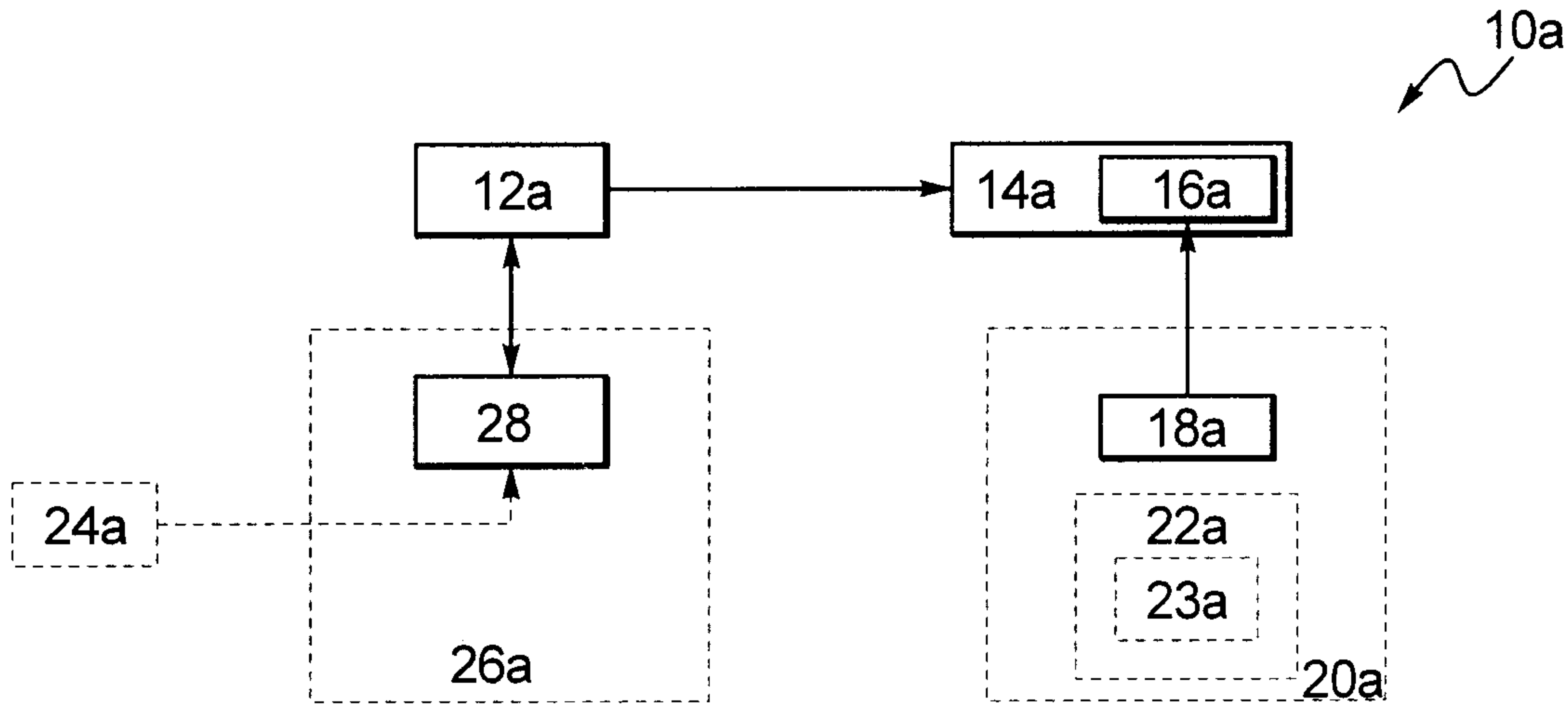


FIG. 2A

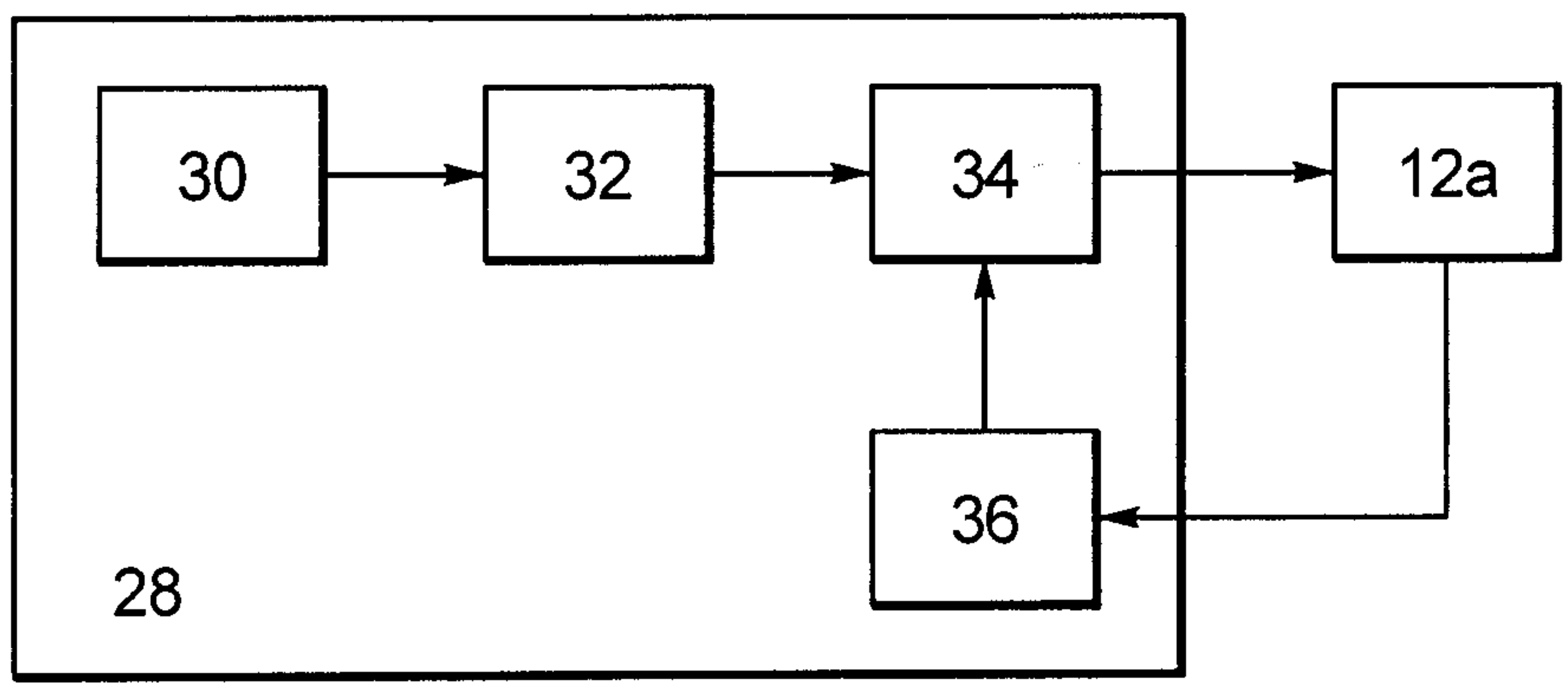


FIG. 2B

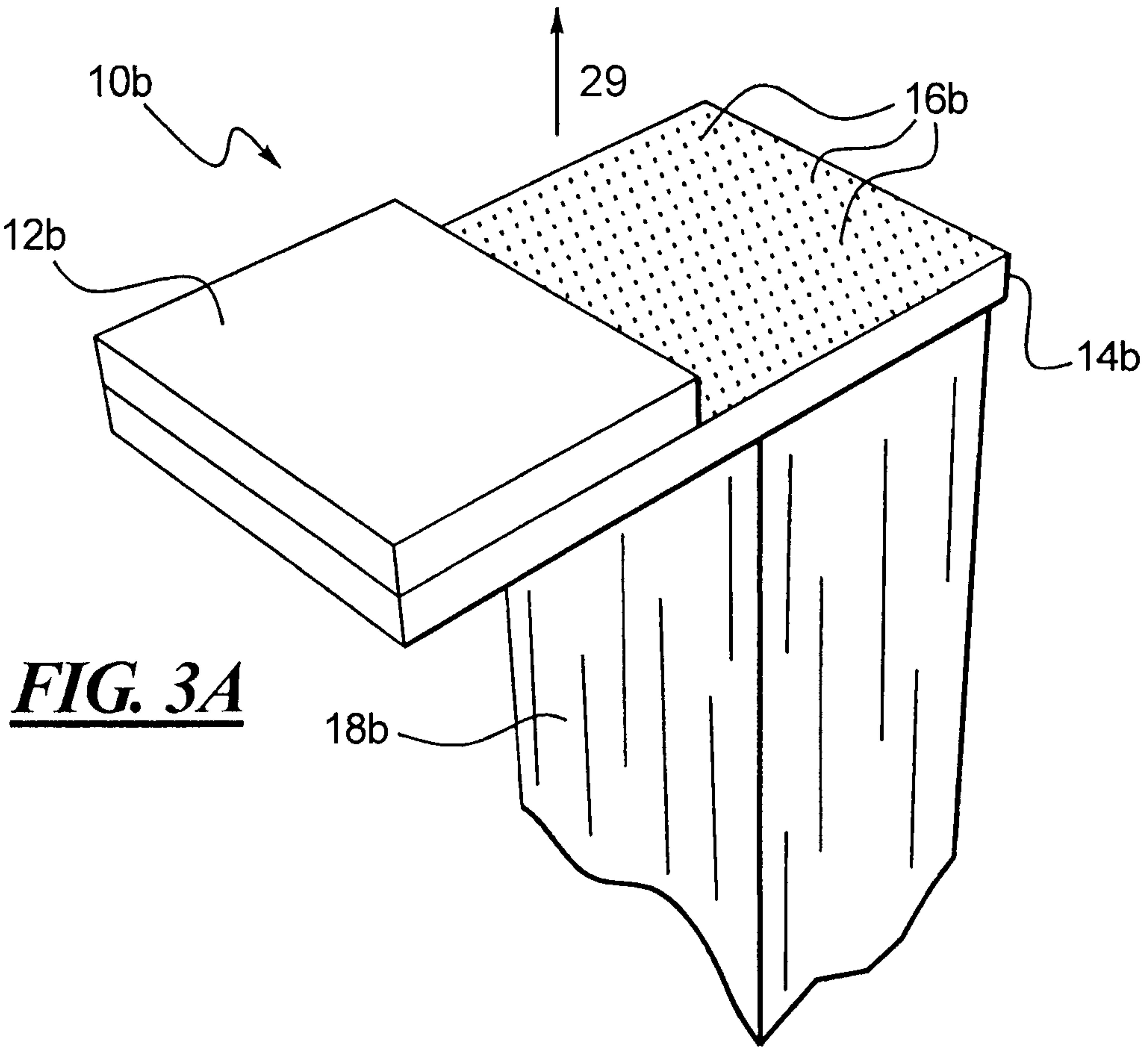


FIG. 3A

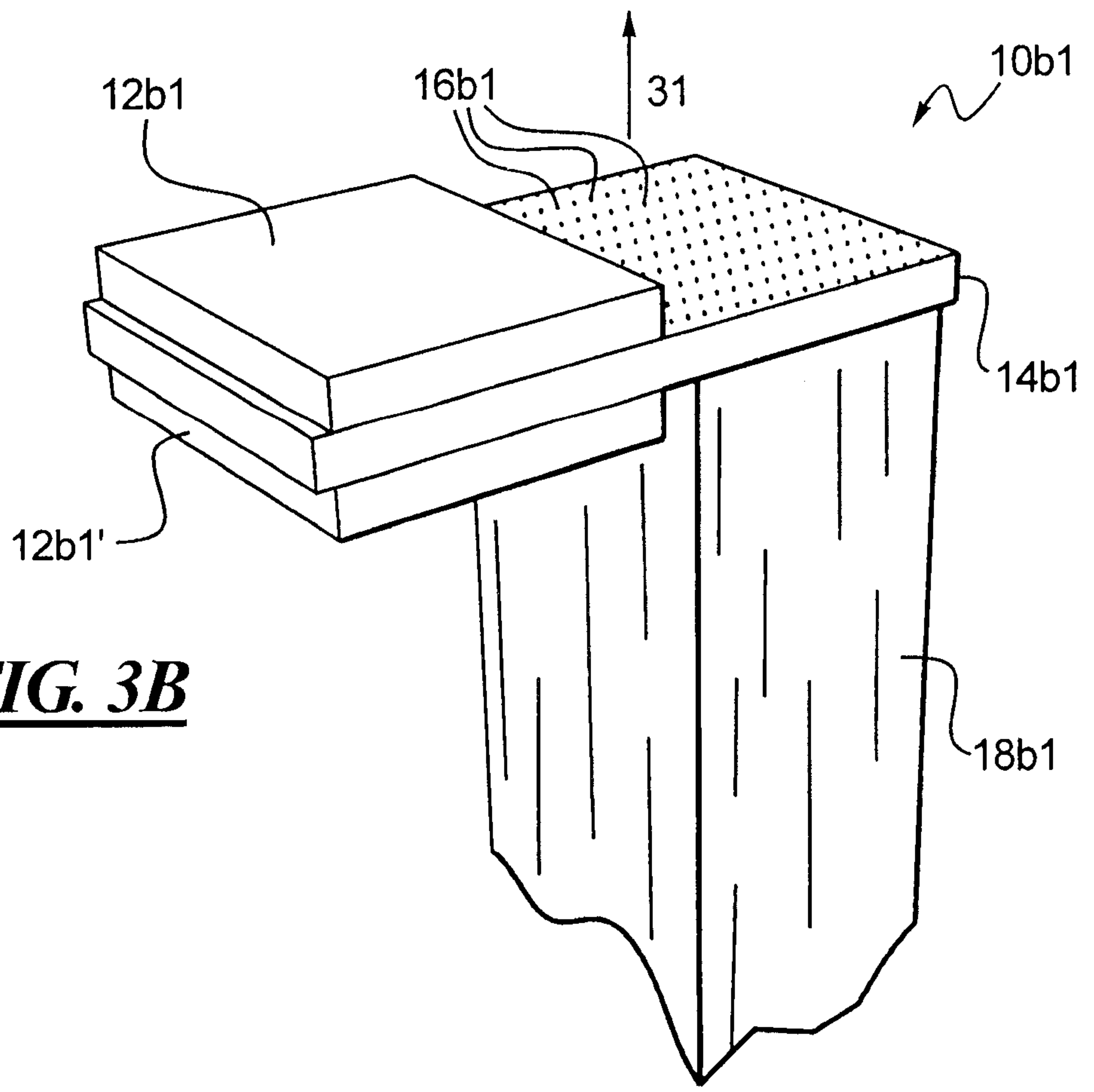
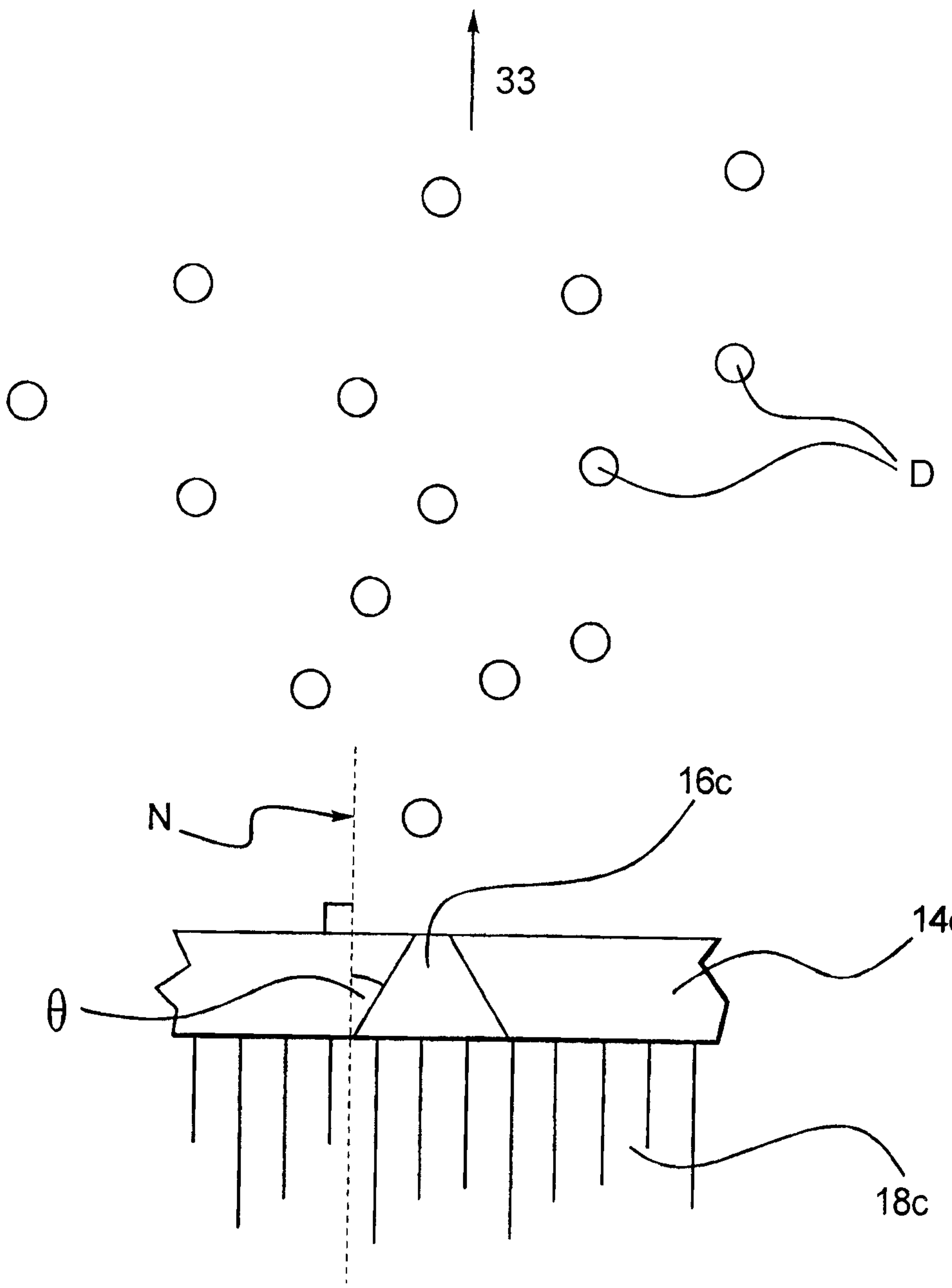


FIG. 3B

FIG. 4A



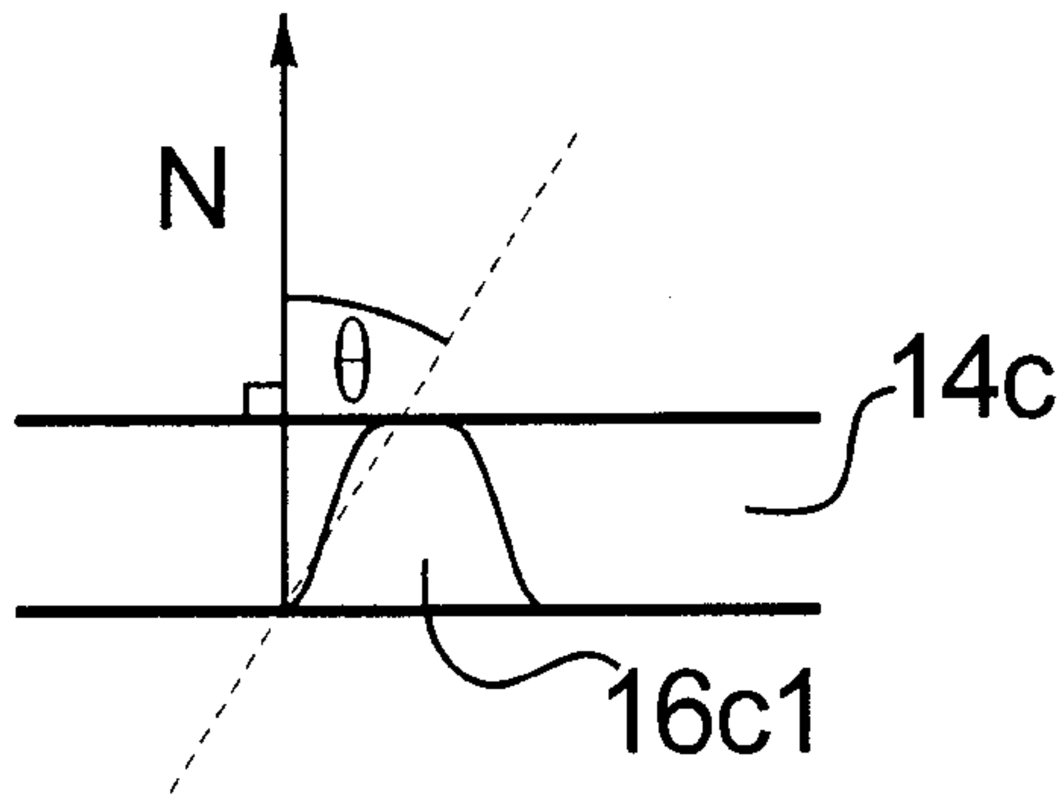


FIG. 4B

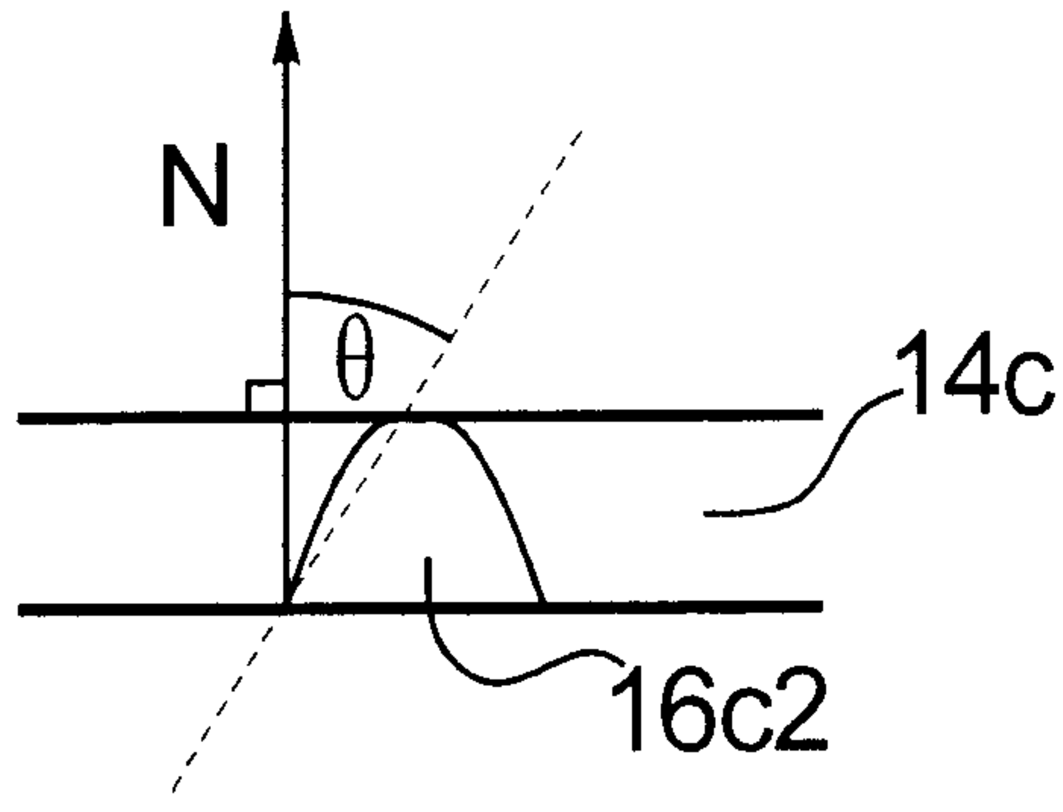


FIG. 4C

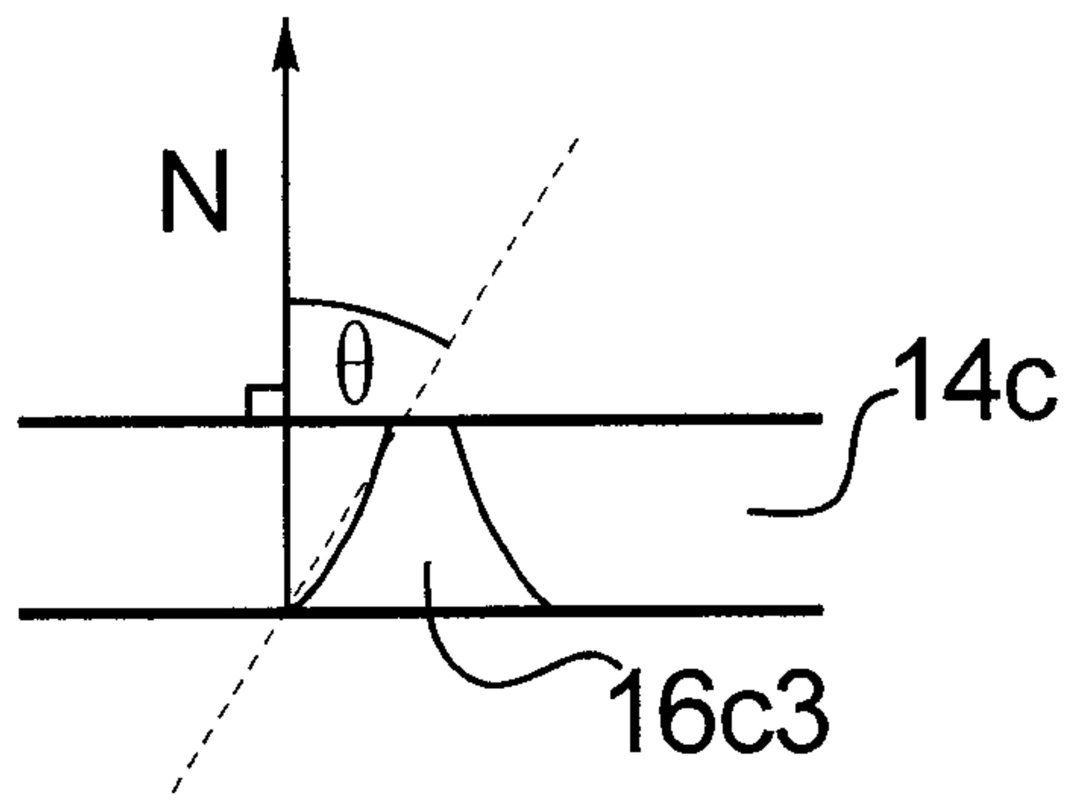


FIG. 4D

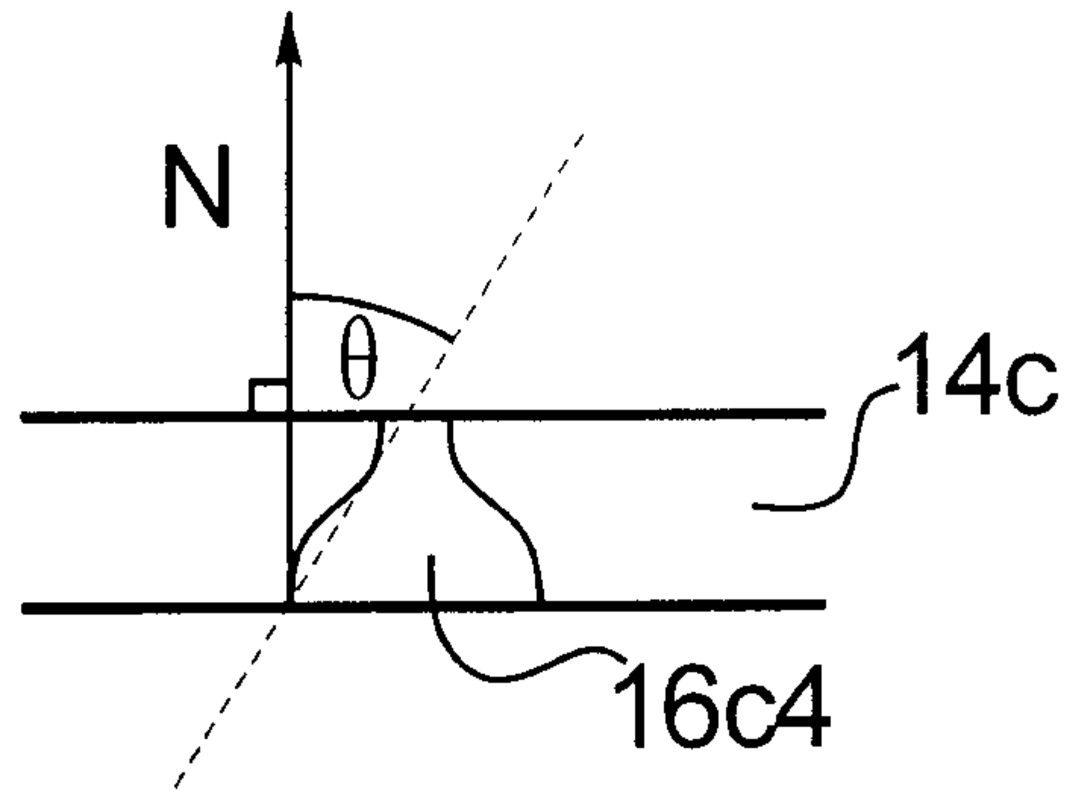


FIG. 4E

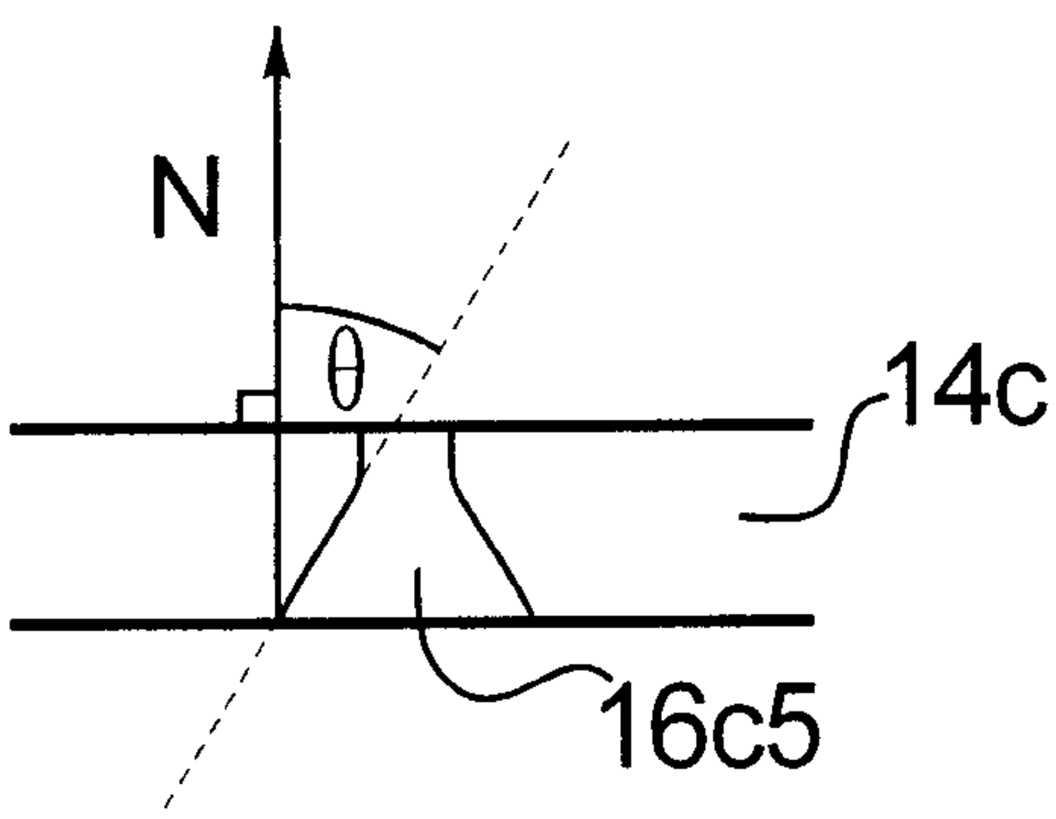


FIG. 4F

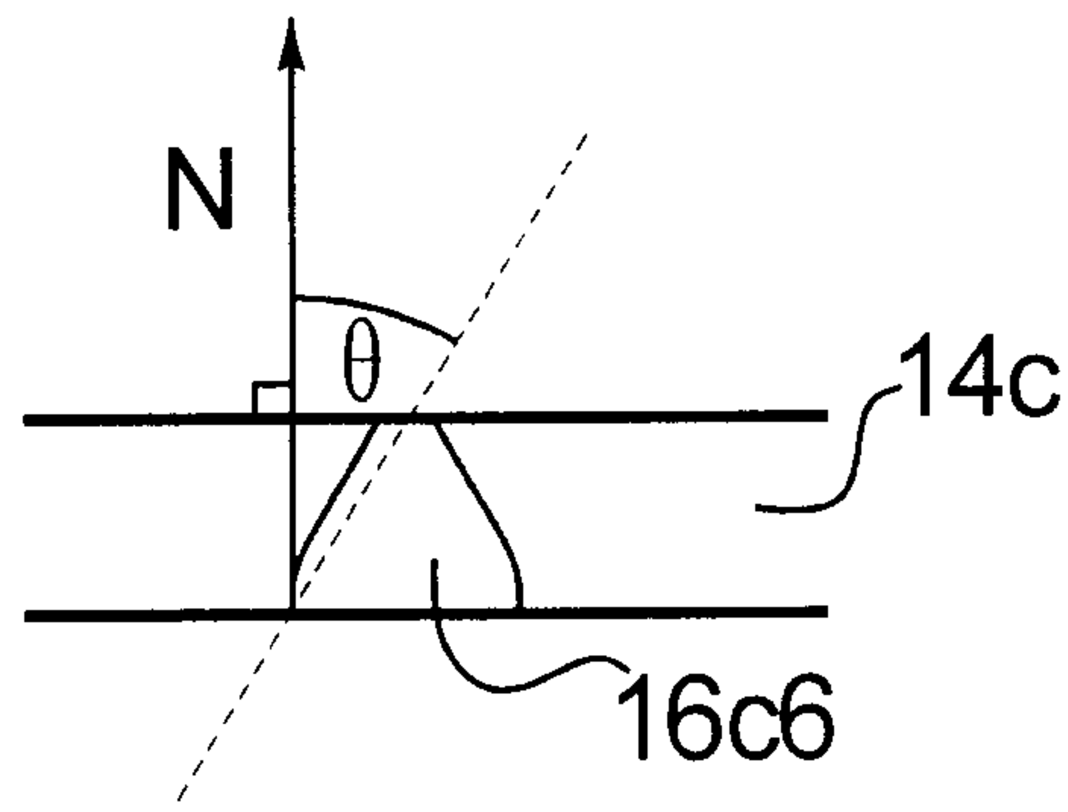


FIG. 4G

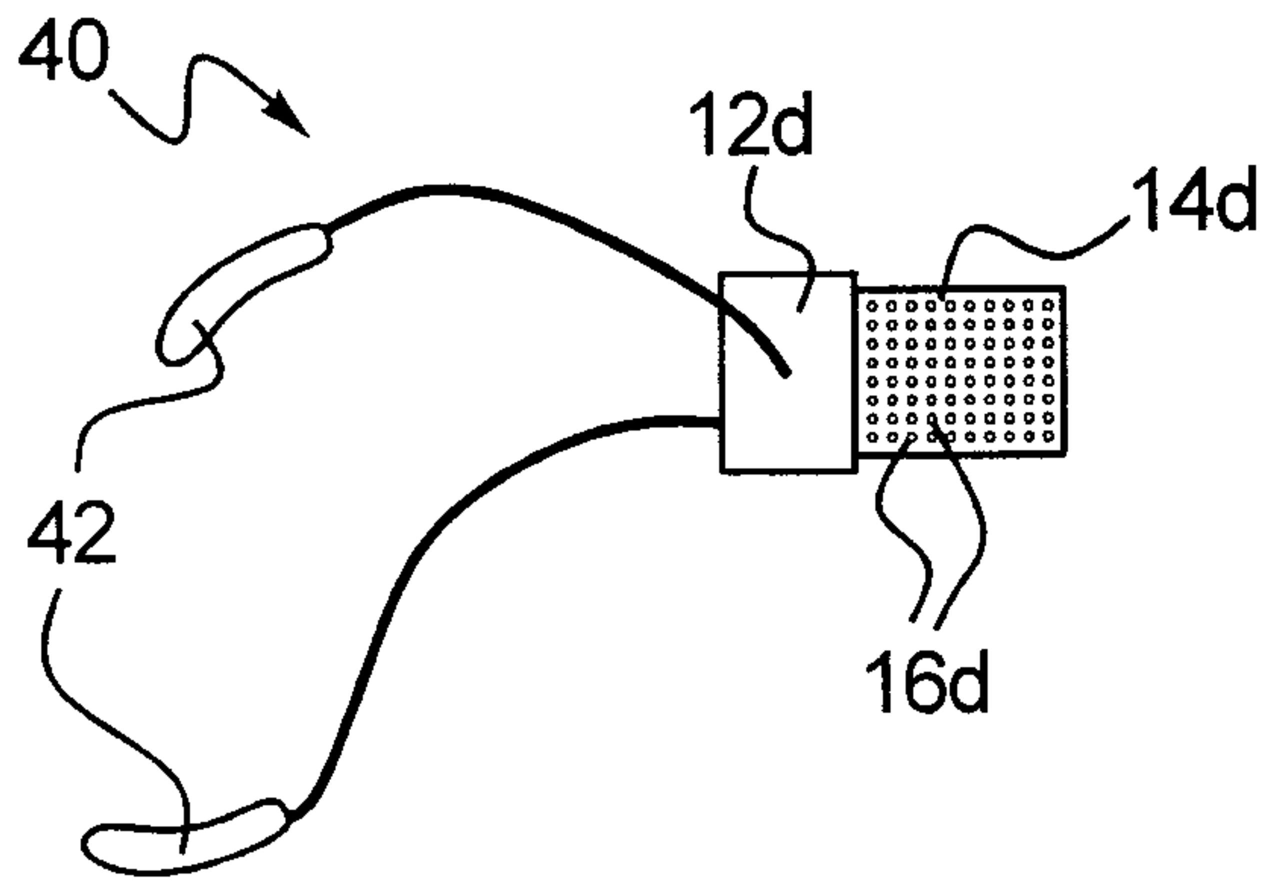


FIG. 5A

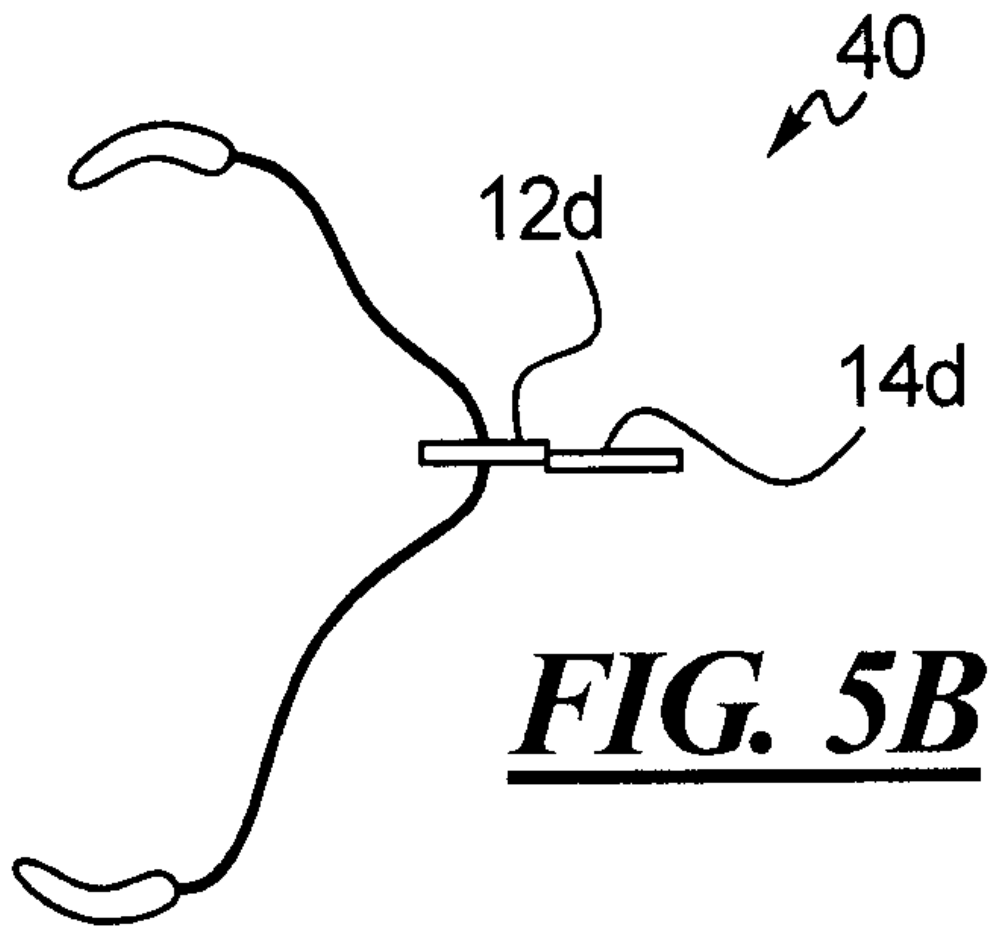


FIG. 5B

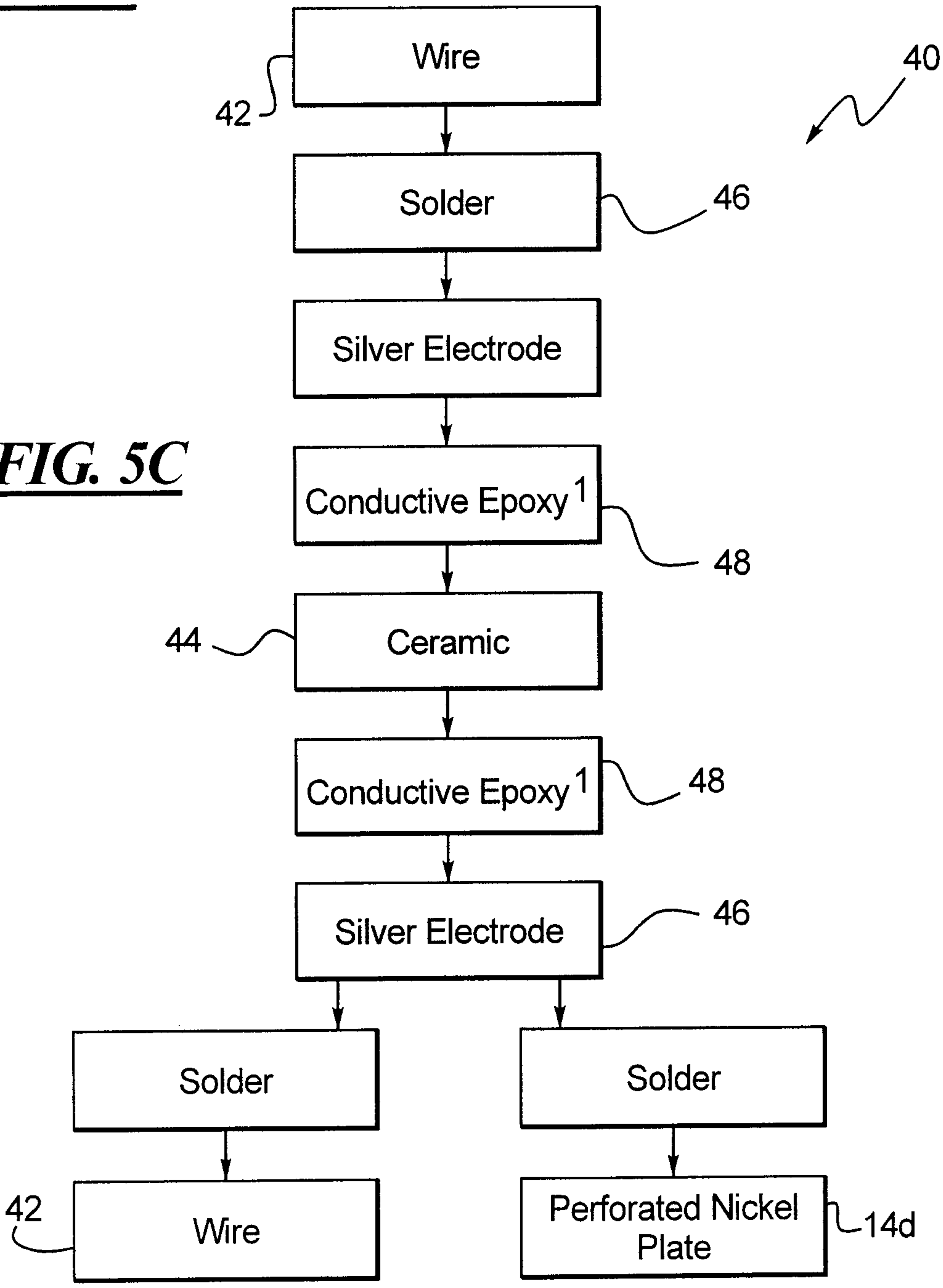


FIG. 5C

FIG. 6A

	A	B
Plate dimensions	15mm x 15mm x 0.08mm	17.7mm x 17.7mm x 0.08 mm
Dimensions of perforated area	12mm x 12mm	17.7mm x 7.7mm
Average perforation area	530 mm2	1960 mm2
Number of perforations	10,800	17,324

FIG. 6D

	A	B
Particle size	26.7 microns	19.4 microns
Plume distance	610mm (24 inches)	457mm (18 inches)
Plate velocity discharge rate	500 mm/sec 0.16 grams/sec	151 mm/sec 0.21 grams/sec

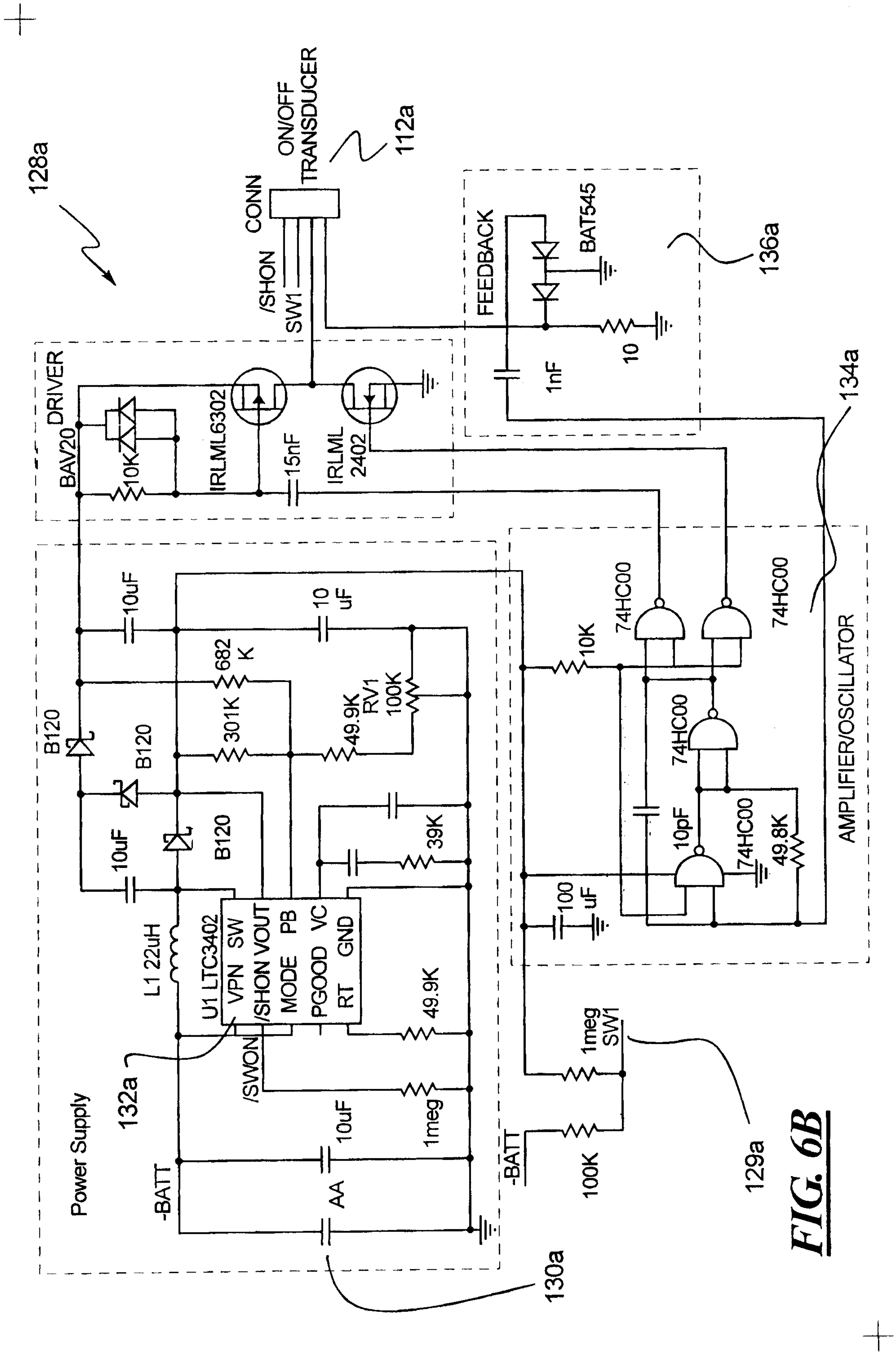

128a
ON/OFF
TRANSDUCER
112a
CONN
/SHON
SW1
DRIVER
BAV20
10K
IRLML6302
15nF
IRLML
2402
FEEDBACK
BAT545
136a
1nF
10
134a
Power Supply
-BATT
AA
10uF
1meg
/SWON
132a
L1 22uH
U1 LTC3402
VPN SW
/SHON VOUT
MODE PB
PGOOD VC
RT GND
49.9K
B120
10uF
B120
B120
301K
682
K
49.9K
RV1
100K
10
uF
10uF
39K
130a
AMPLIFIER/OSCILLATOR
74HC00
74HC00
74HC00
74HC00
10K
10pF
49.8K
100
uF
1meg
SW1
-BATT
100K
129a

FIG. 6B

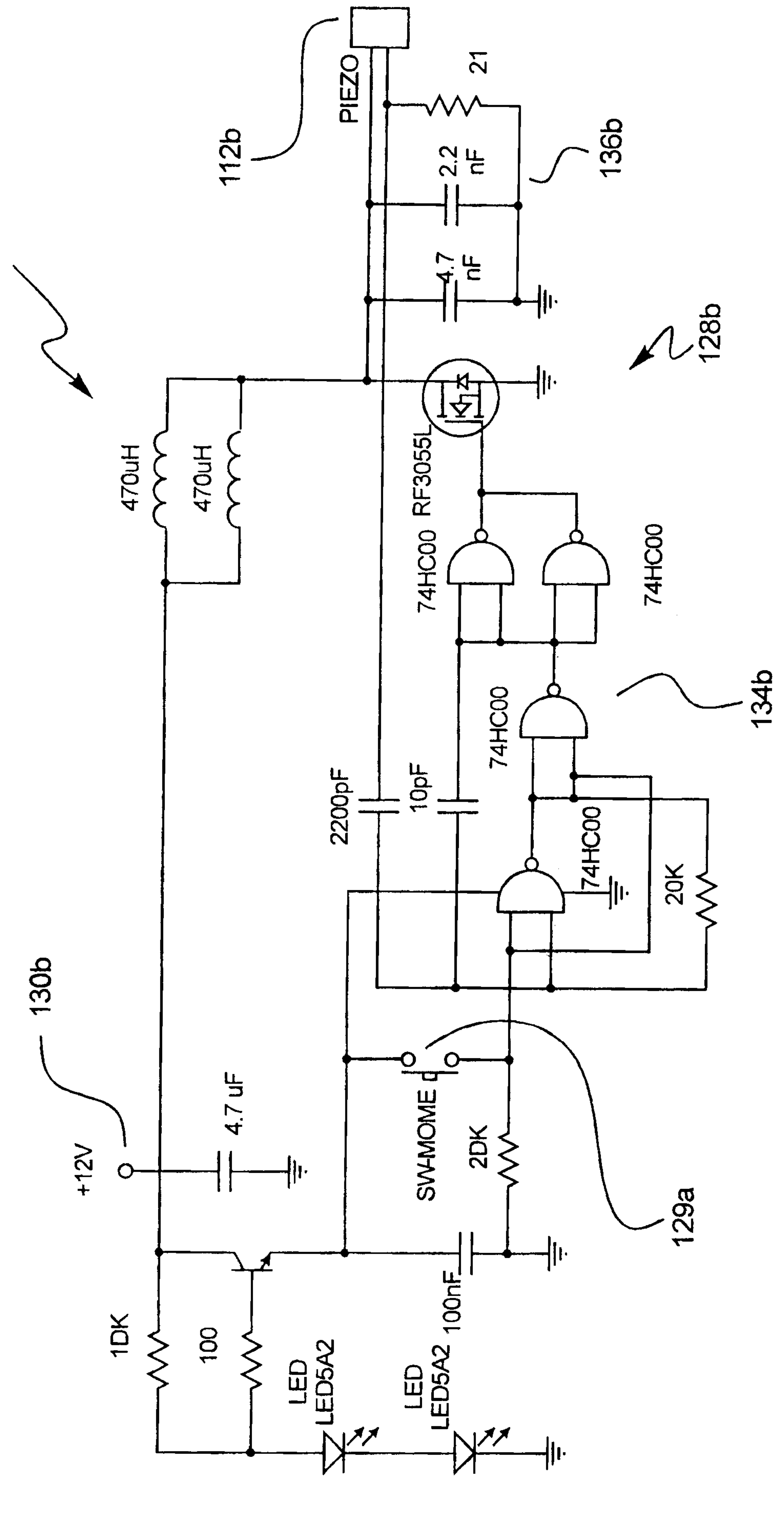
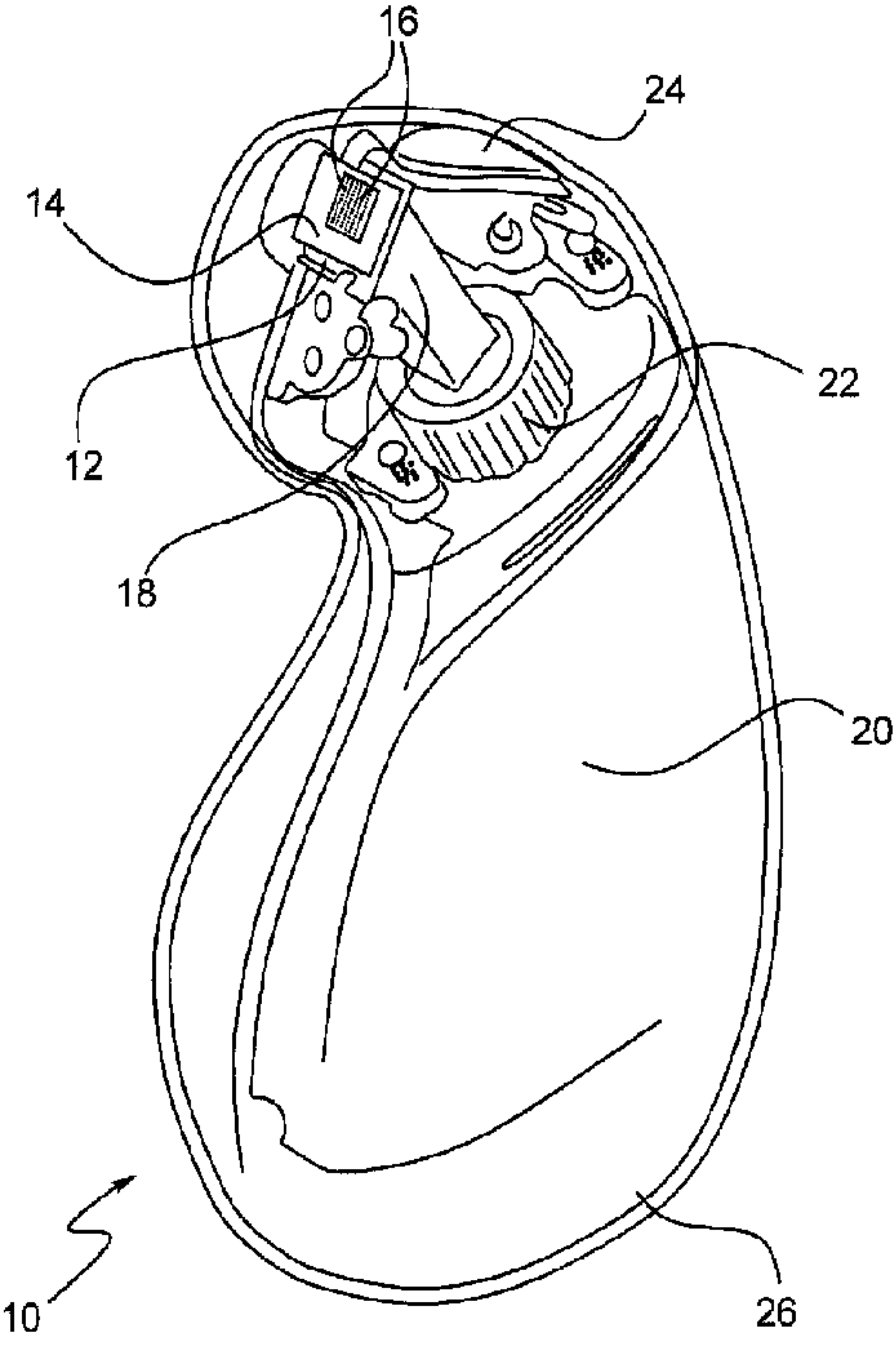

132b
112b
PIEZO
21
2.2
nF
136b
4.7
nF
128b
470uH
470uH
RF3055L
74HC00
74HC00
134b
74HC00
74HC00
2200pF
10pF
20K
130b
+12V
4.7 uF
SW-MOME
2DK
129a
100nF
1DK
100
LED
LED5A2
LED
LED5A2

FIG. 6C



16
24
14
22
12
18
20
10
26