



Office de la Propriété

Intellectuelle
du Canada

Un organisme
d'Industrie Canada

Canadian
Intellectual Property
Office

An agency of
Industry Canada

CA 2532978 C 2014/05/06

(11)(21) **2 532 978**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) Date de dépôt PCT/PCT Filing Date: 2004/07/06
(87) Date publication PCT/PCT Publication Date: 2005/02/03
(45) Date de délivrance/Issue Date: 2014/05/06
(85) Entrée phase nationale/National Entry: 2006/01/18
(86) N° demande PCT/PCT Application No.: US 2004/021628
(87) N° publication PCT/PCT Publication No.: 2005/009323
(30) Priorités/Priorities: 2003/07/18 (US60/488,718);
2004/04/27 (US10/833,932)

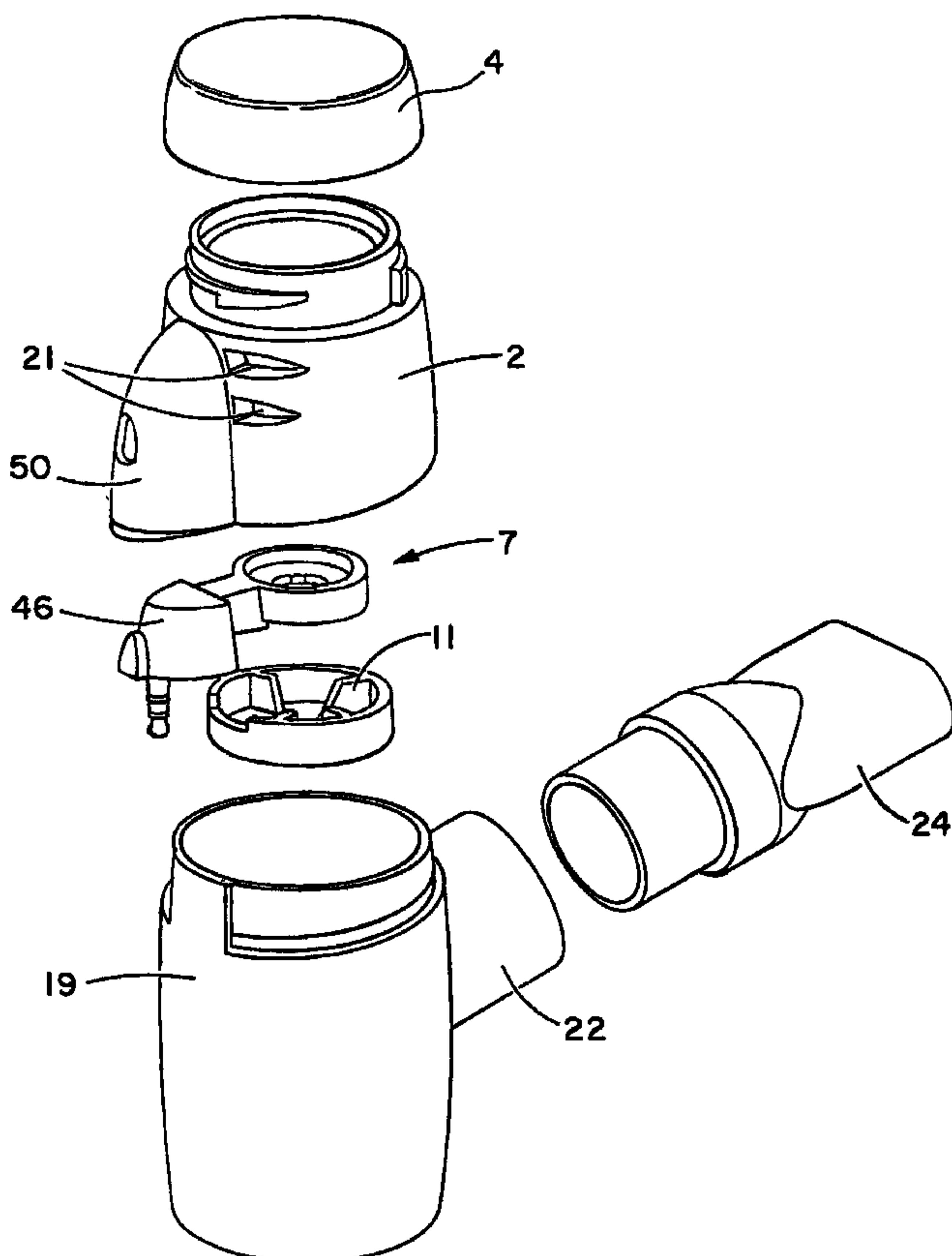
(51) Cl.Int./Int.Cl. *A61M 11/00* (2006.01),
A61M 15/00 (2006.01)

(72) Inventeurs/Inventors:
POWER, JOHN, IE;
MORAN, DECLAN, IE;
DEVERY, DONAL, IE;
O'SULLIVAN, GAVAN, IE;
FINK, JAMES, US;
SMITH, NIALL, IE

(73) Propriétaire/Owner:
NOVARTIS AG, CH

(74) Agent: FETHERSTONHAUGH & CO.

(54) Titre : UN NEBULISEUR POUR LA PRODUCTION DE MEDICAMENT EN AEROSOL
(54) Title: A NEBULISER FOR THE PRODUCTION OF AEROSOLIZED MEDICATION



(57) Abrégé/Abstract:

A nebuliser to deliver a medicament that includes a housing having a reservoir for the medicament, an aerosol generator that can be supplied the medicament from the reservoir, where the generator aerosolizes at least a portion of the medicament into an aerosol, a gas venting inlet to permit a gas to enter the nebuliser and form a mixture with the aerosol, and a passage through which the mixture of the aerosol and the gas is delivered to an outlet port of the nebuliser.



(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization International Bureau



(43) International Publication Date
3 February 2005 (03.02.2005)

PCT

(10) International Publication Number
WO 2005/009323 A3

(51) International Patent Classification⁷: **A01G 23/10**, B05B 1/08, 17/04, A61M 11/00, 11/06, 15/00

(21) International Application Number:
PCT/US2004/021628

(22) International Filing Date: 6 July 2004 (06.07.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/488,718 18 July 2003 (18.07.2003) US
10/833,932 27 April 2004 (27.04.2004) US

(71) Applicant (for all designated States except US): **AERO-GEN, INC.** [US/US]; 2071 Stierlin Court, Mountain View, CA 94043 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **POWER, John**

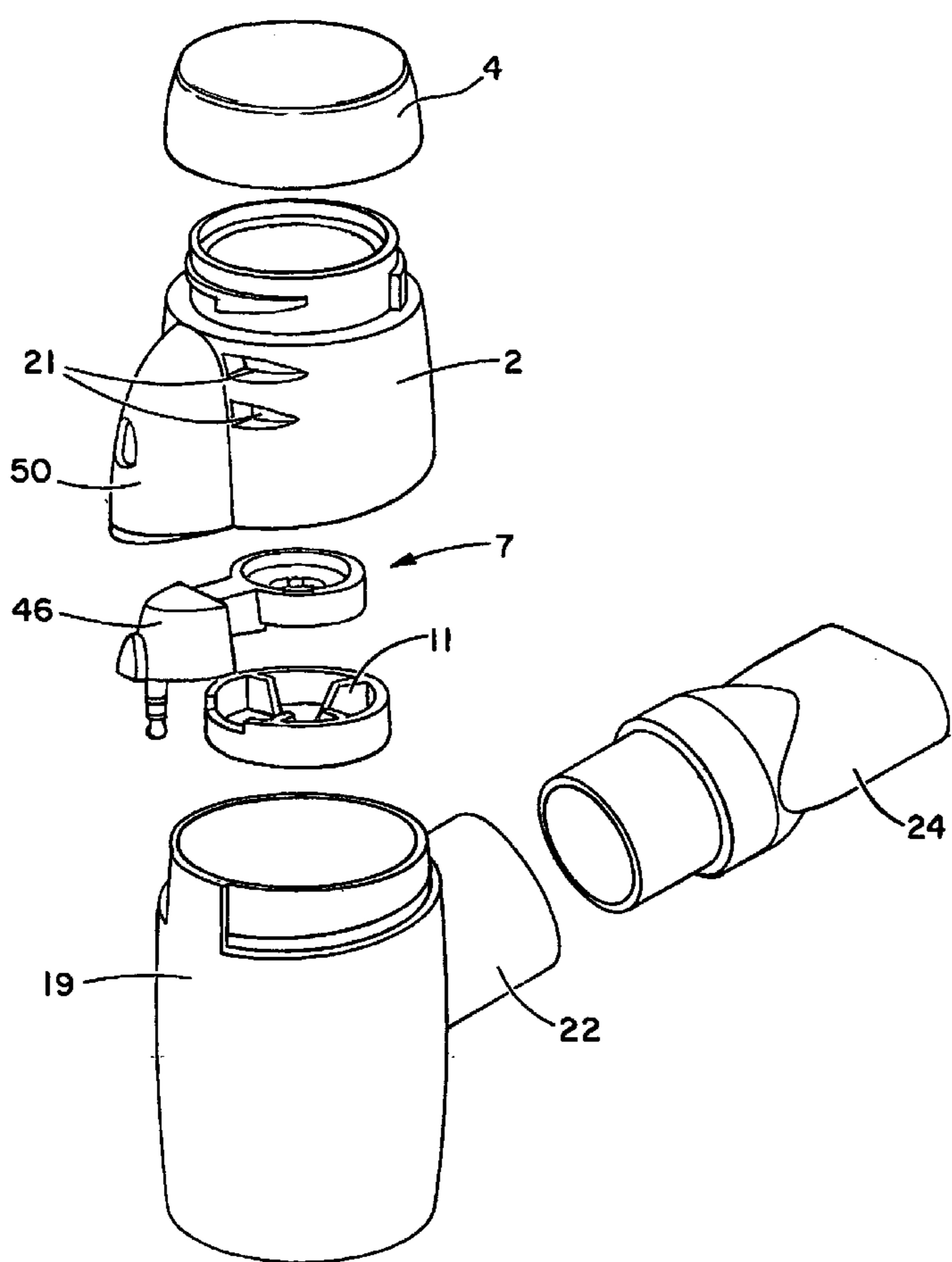
[IE/IE]; 40 Woodland Park, Moycullen, County Galway (IE). **MORAN, Declan** [IE/IE]; Grange Road, Cregmore Turloughmore, County Galway (IE). **DEVERY, Donal** [IE/IE]; School Road, Carnmore, Oranmore, County Galway (IE). **O'SULLIVAN, Gavan** [IE/IE]; Legal Lee, Dorrus Park, Kinvarra, County Galway (IE). **FINK, James** [US/US]; 1525 Seneca Lane, San Mateo, CA 94402 (US). **SMITH, Niall** [IE/IE]; 15 Cresent Green, The Cresent, County Galway (IE).

(74) Agents: **GIBBY, Darin, J.** et al.; Townsend and Townsend and Crew LLP, Two Embarcadero Center, Eighth Floor, San Francisco, CA 94111-3834 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,

[Continued on next page]

(54) Title: A NEBULISER FOR THE PRODUCTION OF AEROSOLIZED MEDICATION



(57) Abstract: A nebuliser to deliver a medicament that includes a housing having a reservoir for the medicament, an aerosol generator that can be supplied the medicament from the reservoir, where the generator aerosolizes at least a portion of the medicament into an aerosol, a gas venting inlet to permit a gas to enter the nebuliser and form a mixture with the aerosol, and a passage through which the mixture of the aerosol and the gas is delivered to an outlet port of the nebuliser.

WO 2005/009323 A3

WO 2005/009323 A3



MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

(88) Date of publication of the international search report:
6 May 2005

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

- (84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI,

21489-11099

A NEBULISER FOR THE PRODUCTION OF AEROSOLIZED MEDICATION

5

BACKGROUND OF THE INVENTION

- [0002] This invention relates to a nebuliser for delivery of medicament to the respiratory system of a patient. Certain conditions such as asthma, chronic obstructive pulmonary disease (COPD), and cystic fibrosis require that prescribed liquid medication be turned into a fine mist, called an aerosol, and then inhaled into the lungs.
- [0003] Nebulisers for creating such an aerosol of medication are known. However, conventional nebulisers for home use are generally large and bulky and are inconvenient to use. Thus, there is a need for compact nebulisers that are more convenient for use at home.
- [0004] Nebulisers have long been used to produce aerosols. There are three major classifications of nebulisers for home use. Compressor driven jet or pneumatic nebulisers utilise a reservoir in which medication is placed below the point of aerosol generation, so that medication is drawn up from the reservoir by the action of the jet, which then shears the fluid into small particles. Aerosol collects in and passes through a chamber above the medication reservoir, driven by the flow of gas that generates the aerosol. This constant flow of aerosol from the nebuliser often exceeds inspiratory flows and volumes generated by the patient and reduces the amount of aerosol available for inspiration, reducing the mass of drug inhaled by the patient. Thus, there remains a need for nebulisers that reduce the amount of flow gas needed to deliver aerosolized medication to a patient.
- [0005] Ultrasonic nebulisers create standing waves in a medication reservoir, above a piezo ceramic element, generating aerosol that collects above the medication reservoir. Aerosol does not leave the collection chamber without active gas flow generated directly by the patient, or by a secondary flow of gas (e.g., fan). This reduces the ability of the ultrasonic to be used with an open aerosol mask. Thus there remains a need for nebulisers that can be used with an open aerosol mask.

- [0006] In both jet and ultrasonic nebulisers droplets that do not leave the aerosol chamber remain on the walls of the chamber or return to the reservoir, contributing to a residual drug remaining in the nebuliser. Thus there remains a need for nebulisers that reduce the amount of residual drug that remains in the nebulizer.
- 5 [0007] A nebuliser is also known which has a medication reservoir connected to a transducer horn placed below a mesh plate. The vibration of the horn pushes the liquid medication through orifices in the mesh plate placed above it. Aerosol is directed up from the aerosol generator. Technical limitations of this technology result in relatively large particle sizes, low output, difficulty in aerosolizing suspensions, and a lack of reservoir to 10 effectively collect aerosol between inspiratory efforts. Thus, there remains a need for nebulizers that generate fine aerosol mists with high output, and which also have a reservoir to collect aerosol between inspiratory efforts.
- BRIEF SUMMARY OF THE INVENTION
- [0008] The present invention includes a nebuliser for delivery of a medicament to a patient's respiratory system. The nebuliser may include a housing that forms a reservoir for a liquid medicament. The medicament may enter the reservoir through an inlet and exit the reservoir through an outlet coupled to an aerosol generator. The generator converts the medicament into an aerosol that may travel through an aerosol passage to an outlet port where the aerosol exits the nebuliser. The nebuliser may also include a gas venting inlet that 15 allows gas (e.g., air) to enter the nebuliser and mix with the aerosolized medicament before the mixture of gas and entrained aerosol exits the nebuliser through the outlet port.
- 20 [0009] In one embodiment gravitational flow of a liquid medicament is supplied from the reservoir to the aerosol generator.
- [0010] The gas venting inlet may be located in close proximity to the aerosol generator.
- 25 [0011] In another embodiment the housing has a baffle to direct gas and entrained aerosol to the outlet port. Said baffle may include an inclined surface oriented to cause aerosol to flow through the outlet. The baffle may be inclined towards the outlet port.
- [0012] In another embodiment the nebuliser may include an aerosol rainout trap. The rainout trap may be adjacent to the outlet port.
- 30 [0013] In another embodiment the nebuliser may include an aerosol trap and aerosol rainout from the baffle is directed into the trap.

- [0014] The aerosol generator may have a protector to protect the aerosol generator against physical damage. The protector may include an upper protector above the aerosol generator and/or a lower protector below the aerosol generator, which may be integral with the nebuliser housing. One or more of the protectors may include a mesh.
- 5 [0015] The nebuliser may include a respiratory connector for connecting the outlet port to a respiratory system. The respiratory connector may include a mouth piece. The respiratory connector may be selected from a group consisting of a mouthpiece, a face mask, and a nasal piece.
- 10 [0016] In another embodiment the nebuliser include an aerosol generator housing in which the aerosol generator is held. The aerosol generator housing may be fixed to the reservoir.
- 15 [0017] In another embodiment the aerosol generator may comprise a vibratable member having a plurality of apertures extending between a first surface and a second surface thereof. The apertures in the vibratable member are sized to aerosolise the medicament by ejecting droplets of medicament such that about 70% or more of the droplets by weight have a size in the range from about 1 to about 6 micrometers.
- [0018] In another embodiment the nebuliser may include a drive circuit for the aerosol generator. The drive circuit may include a push-pull resonant power circuit. The resonant circuit may use an inductive element that has an impedance value substantially equal to the impedance of the piezoelectric element.
- 20 [0019] The resonant circuit may include an inductive element. For example, the resonant circuit may include a pair of MOSFET switches operated as a push-pull (alternate on-off) arrangement.
- 25 [0020] The nebuliser drive circuit may be adapted to be plugged directly to a wall outlet receiving an input of an alternating voltage in the range from 90V to 250V at a frequency range from 50Hz- 60 Hz and producing an alternating voltage output at a frequency range from 50Khz to 300Khz. The circuit may include an inductive element having substantially the same impedance of the nebuliser circuit at the operating frequency.
- 30 [0021] In another embodiment, the nebuliser drive circuit may be adapted for use with batteries receiving an input of voltage in the range from 1.5 to 12 Volt and producing an alternating voltage output at a frequency range from 50Khz to 300Khz. The circuit may

include an inductive element having substantially the same impedance of the nebuliser circuit at the operating frequency.

[0022] Another aspect of the invention includes methods for nebulising a viscous liquid. In one embodiment, a method includes providing a vibratable thin shell member that includes a front surface, a rear surface and a plurality of tapered apertures extending therebetween, the apertures being tapered to narrow from the rear surface to the front surface, vibrating the thin shell member, and sweeping the frequency between two frequency values.

[0023] In another embodiment, a method for nebulising a viscous liquid includes providing a vibratable thin shell member that includes a front surface and a rear surface and a plurality of tapered apertures extending therebetween, the apertures being tapered to narrow from rear surface, to the front surface, vibrating the thin shell member, and supplying heat to a viscous liquid (e.g., a lipid).

[0024] Another embodiment of the invention provides an aerosol generator that includes an electrical connector for supplying electrical power to the aerosol generator, the electrical connector and the current carrying components of the aerosol generator being encased by electrically insulating material.

[0025] Embodiments of the invention also include an aerosol generator assembly that includes an aerosol generator and a power inlet, the assembly being structurally supported by elastomeric encasing, where the encasing may also provide electrical insulation to the assembly. The elastomeric encasing may be produced by a process of injection molding.

[0026] In another embodiment of the invention provides an aerosol generator assembly that includes an aerosol generator and a power inlet encased by an elastomeric structure. The aerosol generator may include a vibratory thin shell member having a rear surface and a front surface and a plurality apertures extending therebetween, the apertures having a size range of about 1 to about 6 microns at their smaller opening.

[0027] Additional novel features shall be set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the following specification or may be learned by the practice of the invention. The features and advantages of the invention may be realized and attained by means of the instrumentalities, combinations, and methods particularly pointed out in the appended claims.

21489-11099

4a

In accordance with this invention there is provided a nebulizer to deliver a medicament comprising: a housing having a reservoir for the medicament; an aerosol generator comprising a vibratable member having a plurality of apertures extending between a first surface and a second surface of the member that can be supplied the medicament from the reservoir, wherein the generator aerosolizes at least a portion of the medicament into an aerosol; a gas venting inlet to permit a gas to enter the nebulizer and form a mixture with the aerosol; a passage through which the mixture of the aerosol and the gas is delivered to an outlet port of the nebulizer; and a drive circuit for the aerosol generator, wherein the drive circuit is configured to, substantially throughout aerosolization, repeatedly change a frequency of vibration of the vibratable member between a first frequency and a second frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0028] The invention will be more clearly understood from the following description thereof given by way of example, in which:
- [0029] Fig. 1 is a perspective view of a nebuliser according to an embodiment of the invention;
- [0030] Fig. 2 is a perspective view of a battery driven controller for use with the nebuliser;
- [0031] Fig. 3 is a perspective view of a mains driven controller for use with the nebuliser;
- [0032] Fig. 4 is a perspective view of a nebuliser according to an embodiment of the invention with a mouth piece fitted;
- 10 [0033] Fig. 5 is a cut-away view of the nebuliser of Fig 4;
- [0034] Fig. 6 is an exploded view of the nebuliser of Figs 4 and 5;
- [0035] Fig. 7 is a perspective view from above of an upper part of the nebuliser;
- [0036] Fig. 8 is a perspective view from below of the upper part of the nebuliser;
- [0037] Figs. 9(a) to 9(d) are perspective views illustrating the mounting and overmoulding 15 of a vibratable member and associated connector for a nebuliser according to an embodiment of the invention;
- [0038] Fig. 10 is a block diagram of a drive for a piezoelectric element;
- [0039] Fig. 11 is a circuit diagram of the drive and load stages of Fig. 10;
- [0040] Figs. 12(a) to 12(d) are circuit diagrams showing operation of the drive of Figs. 10 20 and 11 in four modes labelled mode I to mode 4;
- [0041] Figs. 13 to 15 are views similar to Figs. 4 to 6 of a nebuliser according to an embodiment of the invention that includes a nasal piece fitted;
- [0042] Figs. 16 to 18 are views similar to Figs. 4 to 6 of a nebuliser according to an embodiment of the invention with a face mask adaptor fitted; and
- 25 [0043] Figs. 19 to 21 are views similar to Figs. 4 to 6 of a nebuliser according to another embodiment of the invention.

21489-11099

DETAILED DESCRIPTION OF THE INVENTION

[0044] Referring to the drawings and initially to Figs. 1 to 8 thereof there is illustrated a nebuliser 1 according to an embodiment of the invention for delivery of a medicament to the respiratory system of the patient. The nebuliser 1 comprises a housing having a reservoir, which in this embodiment takes 5 the form of a medication cup 2 for liquid medicament. The medication cup 2 has an upper inlet 3 which is covered by a releasable cap 4. The cap 4 is transparent to allow a user to view the contents of the cup 2. The cup 2 also has a lower outlet to which the medicament flows by gravity. The cup 2 has a lower conical portion 6 to promote the flow of medicament to the outlet. An aerosol generator 7 is mounted at the outlet of the cup 2 to aerosolise the liquid medicament. The aerosol generator 7 is 10 protected against user access from above by a barrier mesh 10 which in this case is integrally formed with the medication cup 2. The aerosol generator 7 is also protected from below by a lower mesh 11 which is separately formed from the medication cup 2. The protector meshes 10, 11 are particularly apparent from Figs. 5, 7 and 8.

[0045] Aerosol generated by the aerosol generator 7 is delivered into a vented aerosol passage 20 defined by a nebuliser body 19. Air passes into the passage 20 through air inlets 21. The air entrains the aerosolised medicament and the entrained aerosolised medicament is delivered from the nebuliser through an outlet port 22 from the passage 20. In this case the inlets 21 are formed by air vents which are located above the aerosol generator 7. The outlet port 22 has an extension or connector piece 23 which is inclined upwardly to direct flow into a respiratory system. In this case the outlet connector 23 20 is fitted with a releasable mouthpiece part 24 which is a push-fit on the connector 23.

[0046] The nebuliser 1 has a baffle to direct air and entrained aerosolised medicament to the outlet 22. In this case the baffle is formed by a floor 25 of the nebuliser body 19. It will be noted that the baffle 25 is inclined downwardly towards the outlet port 22. The arrangement of the inlet 21 on one side of the nebuliser housing, the outlet 22 on a generally opposite side of the housing and the 25 baffle 25 optimises the flow of air and entrained aerosolised medicament to the outlet 22.

[0047] The nebuliser 1 has an aerosol rain-out trap 30 for collecting any larger droplets not entrained in the air. In this case the rain-out trap 30 is between the outlet port 22 and the baffle 25. Any droplets not entrained by the air impinge on the baffle 25 and flow down the incline into the trap 30. Similarly any droplets that may form at the outlet 22 or in the associated connectors are directed to flow into the

21489-11099

trap 30. The trap 30 is readily emptied by opening the nebuliser housing and inverting the bottom of the housing.

[0048] Typically, the medication cup 2 is configured to accommodate up to about 6 ml to about 10 ml of liquid medicament.

5 [0049] The aerosol generator 7 comprises a vibratable member 40 and a piezoelectric element 41. The vibratable member 40 has a plurality of tapered apertures extending between a first surface and a second surface thereof, as described in United States Patent Nos. 5,164,740 (the first '740 patent); 5,586,550 (the '550 patent); 5,758,637 (the '637 patent); and 6,085,740 (the second '740 patent).

10 [0050] The first surface of the vibratable member 40, which in use faces upwardly, receives the liquid medicament from the medication cup 2, and the aerosolised medicament is generated at the second surface of the vibratable member 40 by ejecting droplets of medicament upon vibration of the member 40. In use the second surface faces downwardly. In one case, the apertures in the vibratable member 40 may be sized to produce an aerosol in which about 70% or more of the droplets by weight have a size in the range from about 1 to about 5 micrometers. In another embodiment, about 70% or 15 more (by weight) of the droplets have sizes ranging from about 1 to about 6 micrometers.

[0051] The vibratable member 40 is non-planer, and is preferably dome-shaped in geometry.

20 [0052] The piezoelectric element 41 has an electrical connection socket 45 to which a connector plug element 46 is mounted as illustrated in Figs. 9(a) and 9(b). The piezoelectric element 41 and the connection 45 and plug 46 is then overmoulded to form a sub-assembly 47 which defines a housing 48 for the piezoelectric element 41. The sub-assembly 47 is mounted in the nebuliser housing as illustrated.

25 [0053] The apparatus 1 also includes a controller as illustrated, to control operation of and to supply power to the aerosol generator 7. The plug element 46 defines a signal interface port 50 fixed to the nebuliser housing to receive a control signal from the controller. The controller may be connected to the signal interface port 50 by means of a control lead 52, which has a docking member 51 or connector for mating with the plug 46 at the interface port

50. A control signal and power may be passed from the controller through the lead 52 to the aerosol generator 7 to control the operation of and supply power to the aerosol generator 7.

[0054] As illustrated in Fig 2 in one case a controller 55 may comprise a battery operated unit.

5 [0055] Alternatively, a controller 56 may have a mains plug 57 for connecting directly to a mains power source. In this case the controller has an integral AC-DC circuit as well as control circuitry mounted in a single housing.

10 [0056] Each controller 55 or 56 has a housing 60 and a user interface to selectively control operation of the aerosol generator 7. The user interface may be in the form of, for example, an on-off button 58.

[0057] Status indication means are also provided on the housing 60 to indicate the operational state of the aerosol generator 7. For example, the status indication means may be in the form of a visible LED 61, to indicate an operational state of the aerosol generator 7.

15 [0058] Referring to Figs. 10 to 12 the piezo drive arrangement is illustrated. Power may be from an AC/DC power supply or a DC/DC power supply, in what is illustrated as a Stage 1. Where the former a V_{bus} level of 20V is provided by a universal input (85 V_{ac} - 264 V_{ac}) AC/DC adapter. Where the latter, batteries may provide the power.

[0059] In a Stage 2 a push/pull resonant circuit provides the following output to the load:

$$P_{out} = 1 \text{ W}$$

20 $f_{out} = 128 \text{ kHz}$

$$V_{out} = 54 \text{ V}_{ms}$$

[0060] The resonant circuit comprises a resonant inductor L_{res} and the capacitive element (C_p) of the piezoelectric load, driven by two MOSFETs Q1 and Q2 in a push-pull arrangement. As shown in Fig. 11 the resonant circuit also comprises a $100\mu\text{F}$ bulk capacitor C_{bus} and a DC blocking capacitor C_{dc} .

[0061] Referring particularly to Figs. 12(a) to 12(d) switching period modes Mode 1 to Mode 4, respectively, are illustrated.

Mode 1

- C_{dc} is neglected because its AC ripple is assumed negligible.
- Q1 turned on, Q2 turned off.

21489-11099

- Positive current flow in direction of arrow.
- Mode equations solved using equation:

$$V_{bus} = V_{Lres} + V_{Cp}(t)$$

Mode 2

- 5
- Q1 turning off, Q2 off.
 - Current freewheels through anti-parallel diode of Q2.
 - Mode equation:

$$V_{Lres}(t) + V_{Cp}(t) + V_{DQ2} = 0$$

Mode 3

- 10
- Q1 turned off, Q2 turned on.
 - Positive current flow in direction of arrow.
 - Mode equation:

$$V_{Lres}(t) + V_{cp}(t) = 0$$

Mode 4

- 15
- Q2 turning off, Q1 off.
 - Current freewheels through anti-parallel diode of Q1.
 - Mode equation:

$$V_{Cp}(t) + V_{Lres}(t) - V_{DQ1} - V_{Cbus} = 0$$

[0062] In use, the cap 4 is opened and medicament is delivered through the inlet port 3 into the
20 medication cup 2. Typically a supply container, such as a nebule or a syringe, is used to deliver the liquid medicament through the inlet port 3 into the medication cup 2. The liquid medicament in the medication cup 2 flows by gravitational action towards the aerosol generator 7 at the lower medicament outlet.

[0063] By distancing the inlet port 3 to the medication cup 2 from the aerosol generator 7, this
25 arrangement creates a sterile barrier between the delivery of the liquid medicament into medication cup 2 and the respiratory system of the patient.

[0064] The docking member 51 of the control lead 52 is mated with the signal interface port 50 on the reservoir 2 to connect the controller 55 or 56 to the aerosol generator 7. The controller 55 or 56 may then be activated to supply power and a control signal to the aerosol generator 7, which causes the

21489-11099

piezoelectric element 41 to vibrate the vibratable member 40. This vibration of the vibratable member 40 causes the liquid medicament at the top surface of the member 40 to pass through the apertures to the lower surface where the medicament is aerosolised by the ejection of small droplets of medicament.

- 5 [0065] The aerosolised medicament passes from the aerosol generator 7 into the passage 20 of the housing 19. The aerosolised medicament is entrained with a gas, such as air, which passes into the passage 20 through the inlet 21. The entrained mixture of the aerosolised medicament and the gas then passes out through the outlet 22 and on to the respiratory system of the patient.
- [0066] In this case, the mouthpiece 24 is gripped between the teeth of the user, with the lips sealed 10 around the mouthpiece. The user breathes in and out slowly. On the exhale cycle, exhaled gas flows back along the mouthpiece and into the passage 20. Exhaust may pass through the gas inlets 21. Breathing is continued in this way until aerosol formation has stopped indicating that all the medicament in the medication cup 2 has been delivered into the patient's respiratory system. The nebuliser is turned off by pressing the on/off button 58.
- 15 [0067] A suitable material for the various connectors and housings is ABS. An alternative material for the various connectors and housings is polycarbonate or polysulphone. By manufacturing these components of the apparatus from polysulphone or polycarbonate, this enables these components to be autoclaved for multiple use of the same apparatus.
- [0068] Referring now to Figs. 13 to 15 there is illustrated a nebuliser as described above with a nasal 20 piece 70 attached. The nasal piece 70 is used to deliver the medicament through the user's nose.
- [0069] Referring now to Figs. 16 to 18 there is illustrated a nebuliser as described above which in this case has an elbow connector 75 for connection to a face mask 76.
- [0070] Referring to Figs. 19 to 20 there is illustrated another nebuliser 80 which is similar in some respects to the nebulisers described above and like parts are assigned the same reference numerals. In 25 this case air is supplemented by an oxygen supply which is connected through an inlet port 81. A holder 82 is releasably mounted to the nebuliser housing. The holder accepts an external filter which collects all exhaled aerosol. In addition, the holder serves as a diffuser to the jet of gas entering through the inlet port, reducing turbulence and impactive losses of aerosol within the nebuliser housing.

- [0071] The invention provides a nebuliser which is relatively small, light weight and is easy to use. The controllers are also small and light weight. Aerosol is readily generated and efficiently entrained in a gas flow for ease and efficiency of patient use without medical supervision. The nebuliser may be tilted significantly from the vertical (by up to 45°) without significantly effecting functionality. Thus, the nebuliser may be easily used by patients whilst sitting down or at least partially lying down. The gravity dependent orientation of the aerosol generator and the internal volume in the nebuliser provided by the chamber increases inhaled mass of aerosol in such a way that cough reflex is inhibited. The inclusion of the filter in a dependent position reduces risk of second hand aerosol exposure.
- [0072] We have found that delivery of non-newtonian fluids can be aided by sweeping the driving frequency of the piezo across the aperture plates' delivery range. It is thought that the aperture plate alters its mode of vibration depending on the drive frequency. This change of motion applies additional stresses to the fluid which can thin it. The frequency sweep may be achieved by using one of the PWM (pulse width modulation) outputs of the microcontroller and routing this signal to the input of a half bridge or MOSFET driver.

[0073] In this method the frequency changes by the resolution of the system clock (in our case it is $T_{osc}/4$ - 20 Mhz crystal / 14 = 5 Mhz. $T = 1/F_{osc} = 0.2 \mu\text{sec}$. So at approx 130Khz the frequency can change by approx 3kHz for each step.) The delivery range is about 120 kHz to 135kHz. The rate of change of the sweep and range may be controlled using software in the micro controller.

[0074] The invention is not limited to the embodiments hereinbefore described which may be varied in construction and detail.

[0075] The words "comprise," "comprising," "include," "including," and "includes" when used in this specification and in the following claims are intended to specify the presence of stated features, integers, components, or steps, but they do not preclude the presence or addition of one or more other features, integers, components, steps, or groups.

21489-11099

CLAIMS:

1. A nebuliser to deliver a medicament comprising:
 - a housing having a reservoir for the medicament;
 - an aerosol generator comprising a vibratable member having a plurality of apertures extending between a first surface and a second surface of the member that can be supplied the medicament from the reservoir, wherein the generator aerosolizes at least a portion of the medicament into an aerosol;
 - a gas venting inlet to permit a gas to enter the nebuliser and form a mixture with the aerosol;
 - 10 a passage through which the mixture of the aerosol and the gas is delivered to an outlet port of the nebuliser; and
 - a drive circuit for the aerosol generator,
 - wherein the drive circuit is configured to, substantially throughout aerosolization, repeatedly change a frequency of vibration of the vibratable member between a first frequency and a second frequency.
2. A nebuliser according to claim 1, wherein the medicament is supplied from the reservoir to the aerosol generator by gravitational flow.
3. A nebuliser according to claim 1, wherein the gas venting inlet is located in close proximity to the aerosol generator.
- 20 4. A nebuliser according to claim 1, wherein the housing has a baffle to direct the mixture of the gas and the aerosol to the outlet port.
5. A nebuliser according to claim 4, wherein the baffle comprises an inclined surface oriented to cause aerosol to flow through the outlet port.

21489-11099

6. A nebuliser according to claim 4, wherein the baffle is inclined towards the outlet port.

7. A nebuliser according to claim 1, wherein the nebuliser comprises an aerosol rainout trap.

5 8. A nebuliser according to claim 7, wherein the rainout trap is adjacent to the outlet port.

9. A nebuliser according to claim 1, wherein the aerosol generator has a protector to protect the aerosol generator against physical damage.

10. A nebuliser according to claim 9, wherein the protector comprises an upper 10 protector above the aerosol generator.

11. A nebuliser according to claim 9, wherein the protector comprises a lower protector below the aerosol generator.

12. A nebuliser according to claim 10 wherein the upper protector comprises a mesh.

15 13. A nebuliser according to claim 11 wherein the lower protector comprises a mesh.

14. A nebuliser according to claim 11, wherein the lower protector is integral with the nebuliser housing.

20 15. A nebuliser according to claim 1, wherein the nebuliser comprises a respiratory connector to connect the outlet port to a respiratory system.

16. A nebuliser according to claim 15, wherein the respiratory connector comprises a mouth piece.

17. A nebuliser according to claim 15, wherein the respiratory connector is selected from a group consisting of a mouthpiece, a face mask, and a nasal piece.

21489-11099

18. A nebuliser according to claim 1, wherein the nebuliser comprises an aerosol generator housing in which the aerosol generator is held.
19. A nebuliser according to claim 18, wherein the aerosol generator housing is fixed to the reservoir.
- 5 20. A nebuliser according to claim 1, wherein the apertures in the vibratable member are sized to aerosolize the medicament by ejecting droplets of medicament such that about 70% or more of the droplets by weight have a size in the range from about 1 to about 6 micrometers.
- 10 21. A nebuliser according to claim 1, wherein the drive circuit comprises a push-pull resonant power circuit.
22. A nebuliser according to claim 21, wherein the vibratable member comprises a piezoelectric element and the push-pull resonant power circuit comprises an inductive element having an impedance value substantially equal to an impedance of the piezoelectric element.
- 15 23. A nebuliser according to claim 21, wherein the push-pull resonant power circuit comprises an inductive element.
24. A nebuliser according to claim 21, wherein the push-pull resonant power circuit comprises a pair of MOSFET switches operated in an on-off arrangement.
25. A nebuliser according to claim 1, comprising an electrical connector for supplying electrical power to the aerosol generator.
- 20 26. A nebuliser according to claim 1, comprising an aerosol generator assembly that includes a power inlet coupled to the aerosol generator, wherein at least a portion of the assembly is encased by an electrically insulating elastomeric casing.
27. A nebuliser according to claim 26, wherein the elastomeric encasing is produced by a process of injection molding.

21489-11099

28. A nebuliser according to claim 1, wherein the drive circuit is coupled to the aerosol generator and adapted to be plugged directly to a wall outlet receiving an input of an alternating voltage in the range from about 90V to about 250V at a frequency from about 50Hz to about 60 Hz, and producing an alternating voltage output at an operating frequency 5 range from about 50Khz to about 300Khz.
29. A nebuliser according to claim 28, wherein the drive circuit includes an inductive element having a substantially same impedance of the nebuliser circuit at the operating frequency.
30. A nebuliser according to claim 1, wherein the drive circuit is coupled to the aerosol generator and adapted for use with batteries receiving an input of voltage in the range 10 from 1.5 to 12 Volt and producing an alternating voltage output at an operating frequency range from 50Khz to 300Khz.
31. A nebuliser according to claim 30, wherein the drive circuit comprises an inductive element having a substantially same impedance of the said nebuliser circuit at the 15 operating frequency.
32. A nebuliser according to claim 1, wherein the gas entering the nebuliser comprises air.

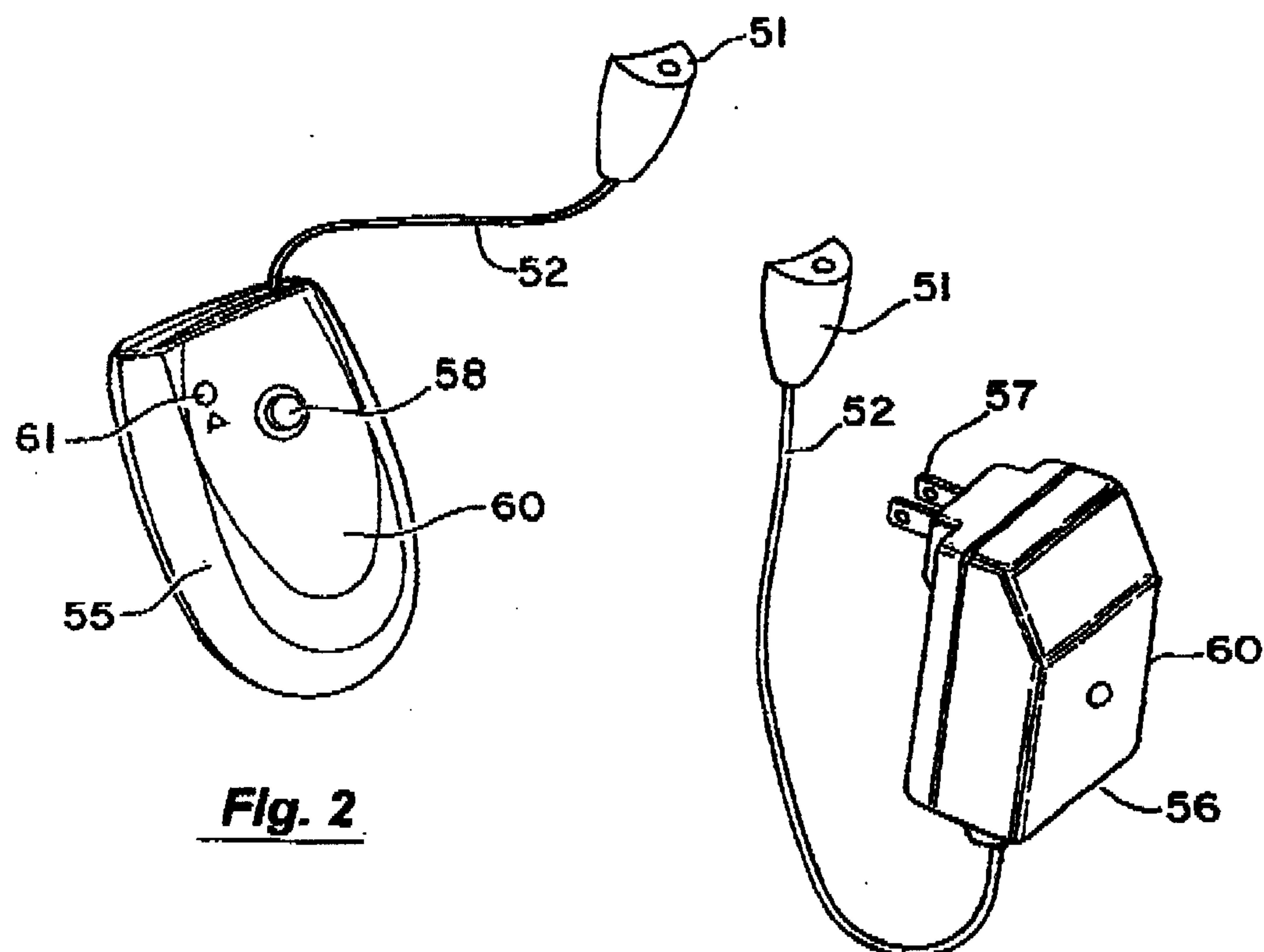
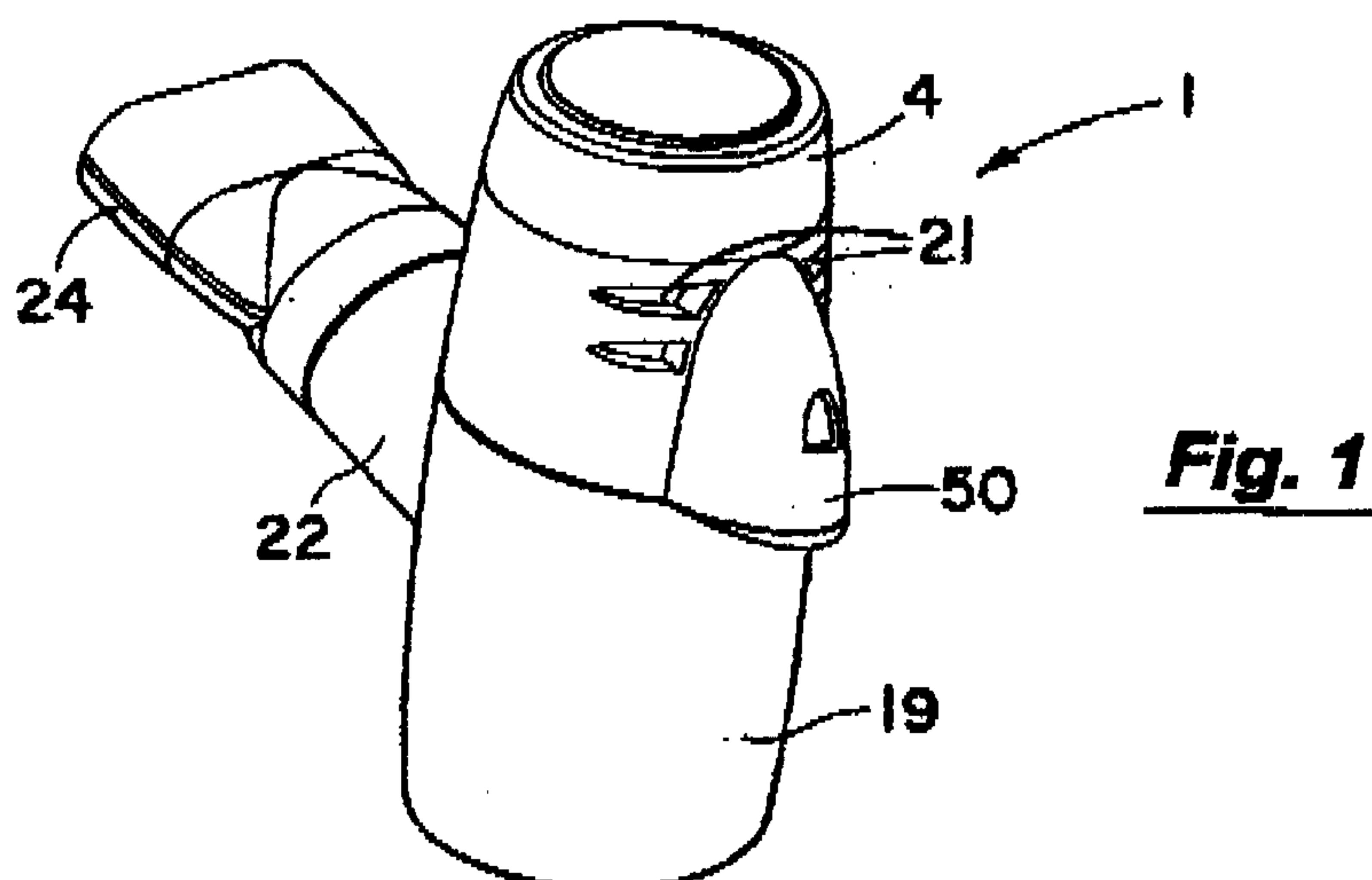


Fig. 3

2/17

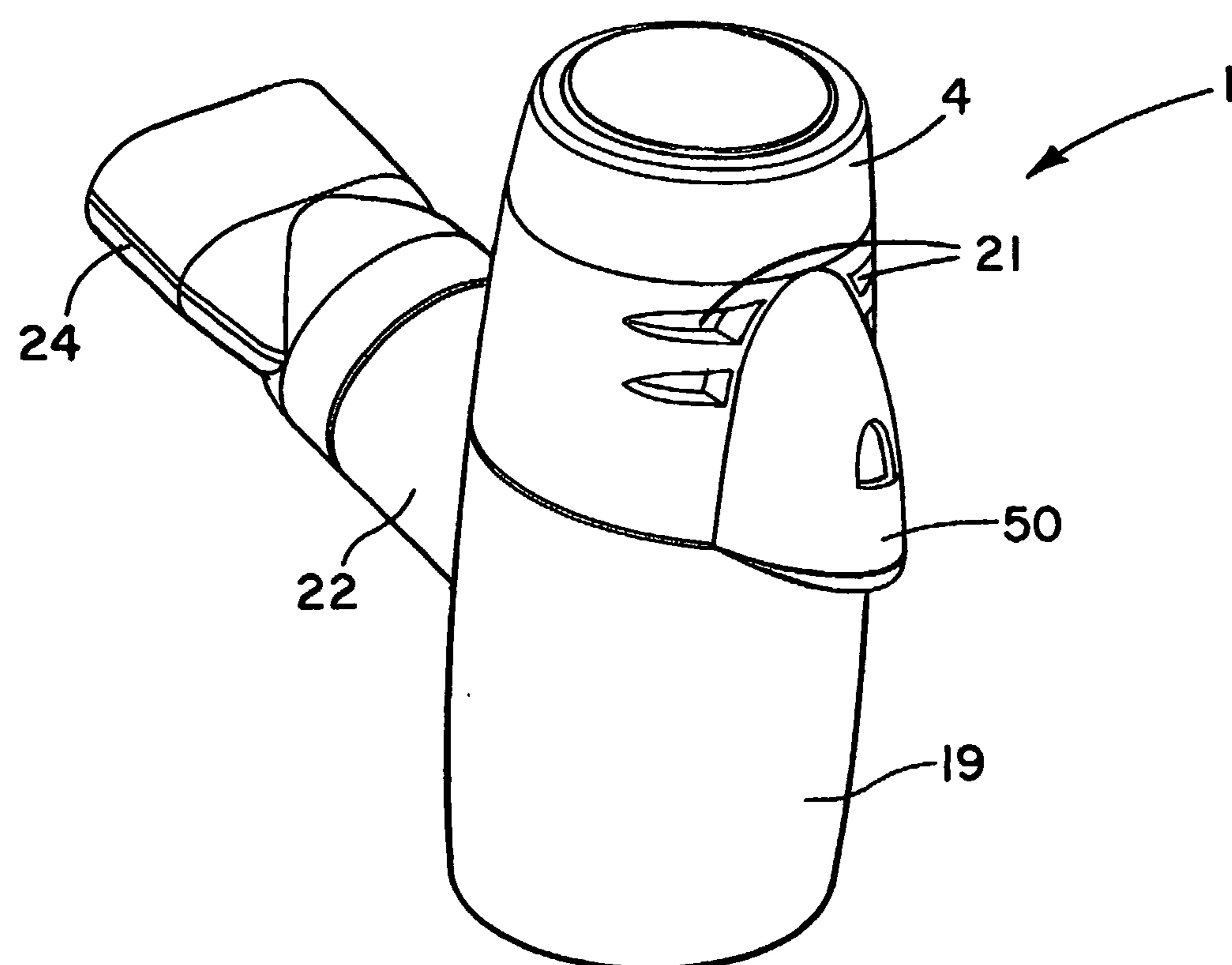


Fig. 4

3/17

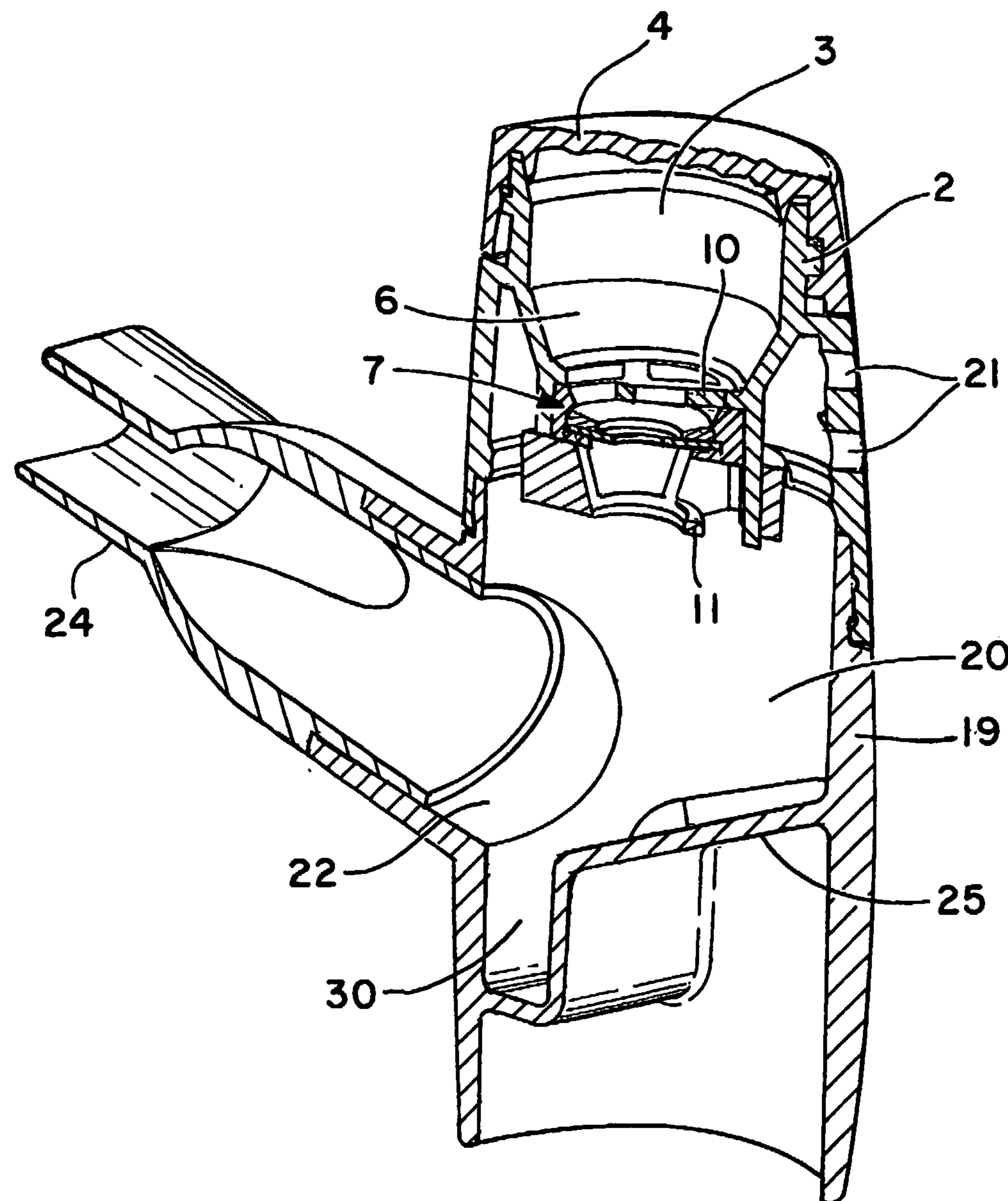


Fig. 5

4/17

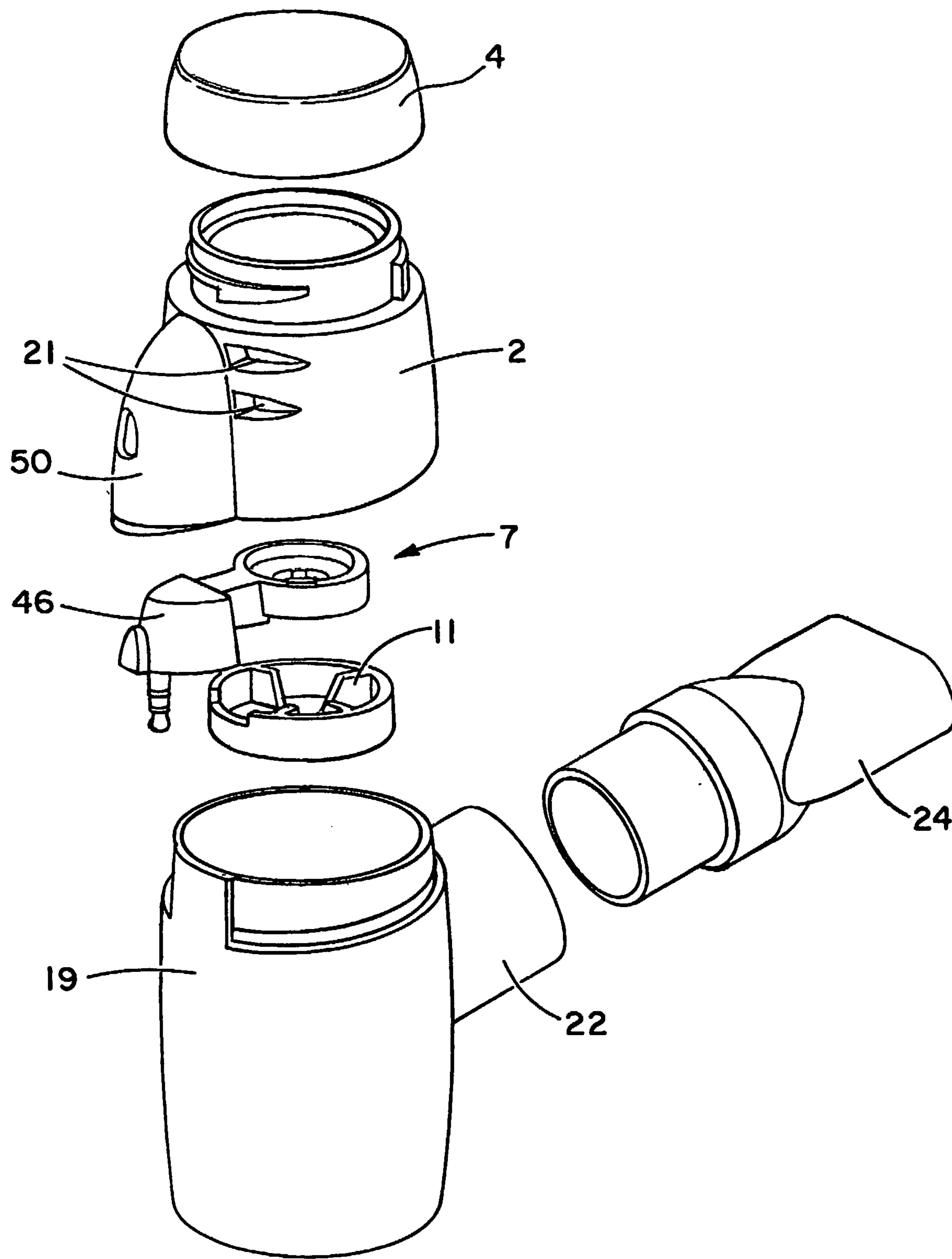


Fig. 6

5/17

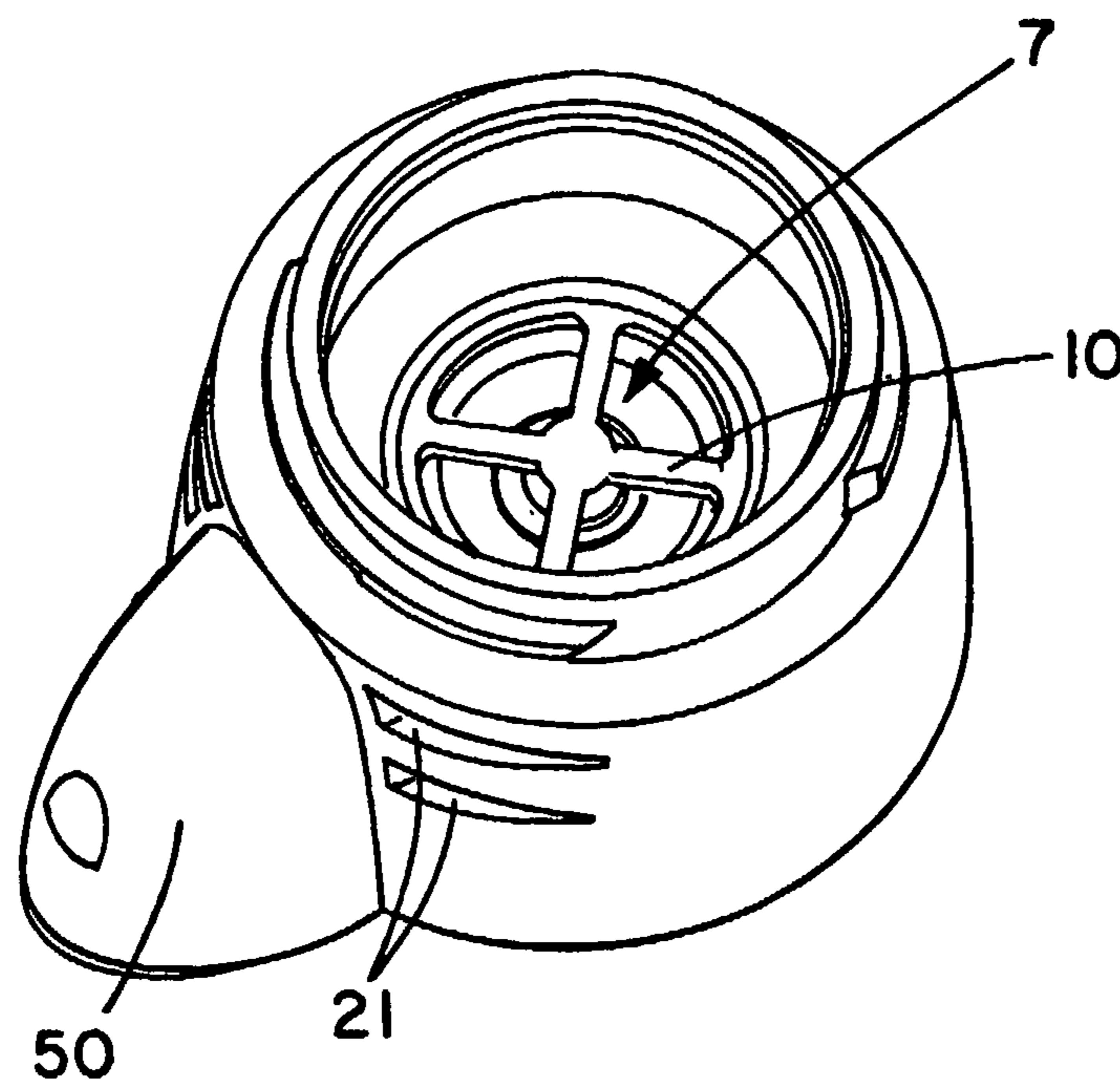


Fig. 7

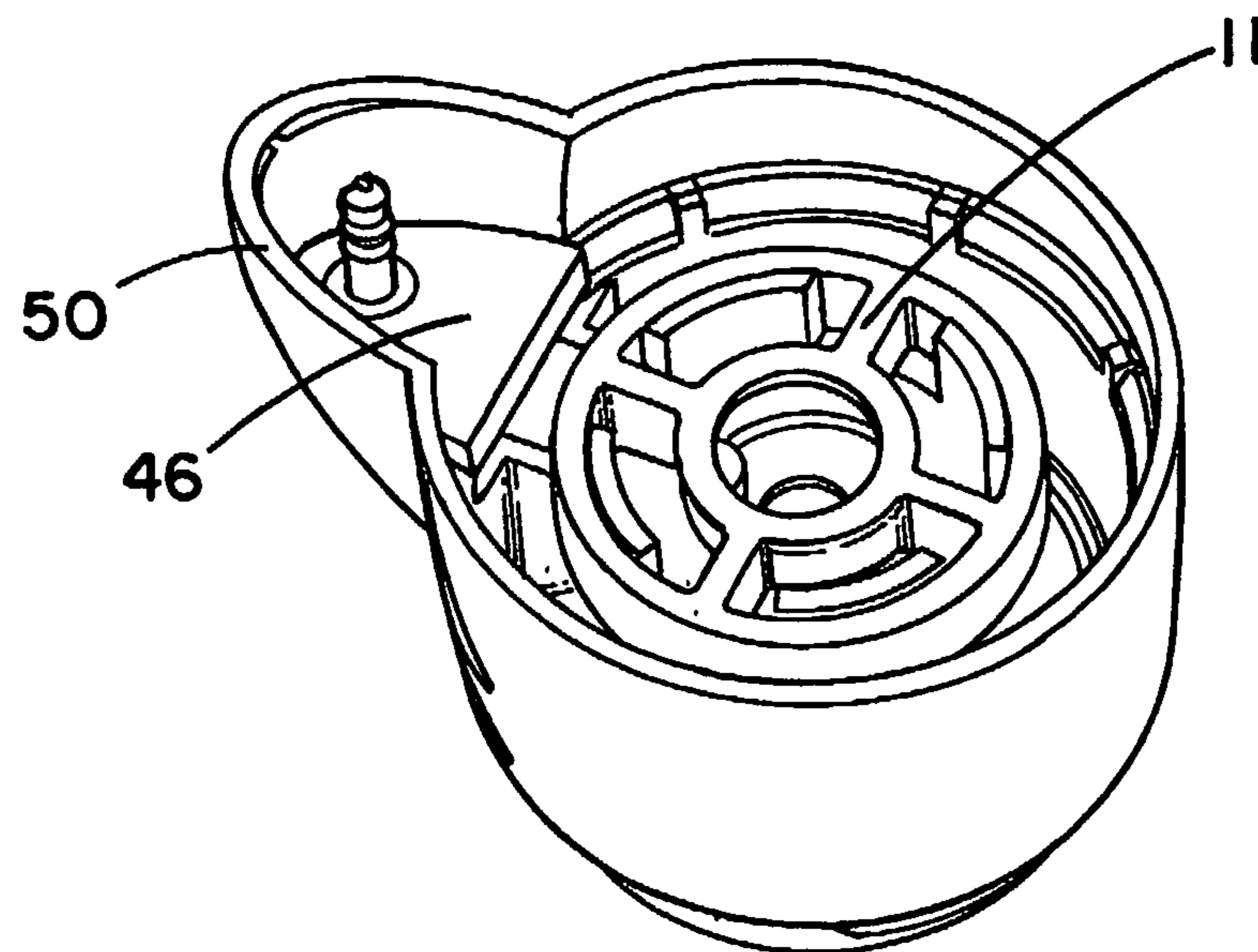


Fig. 8

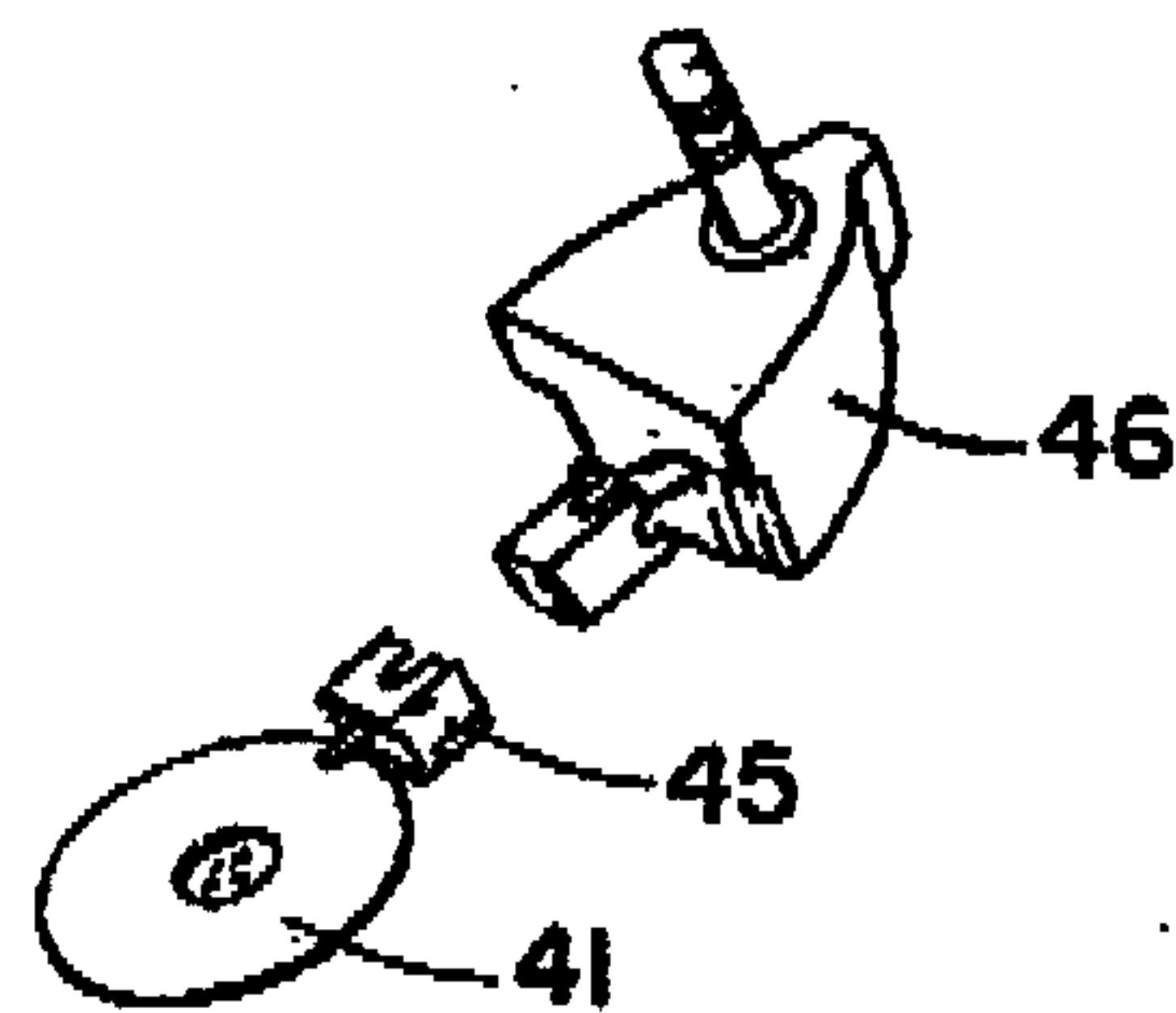


Fig. 9(a)

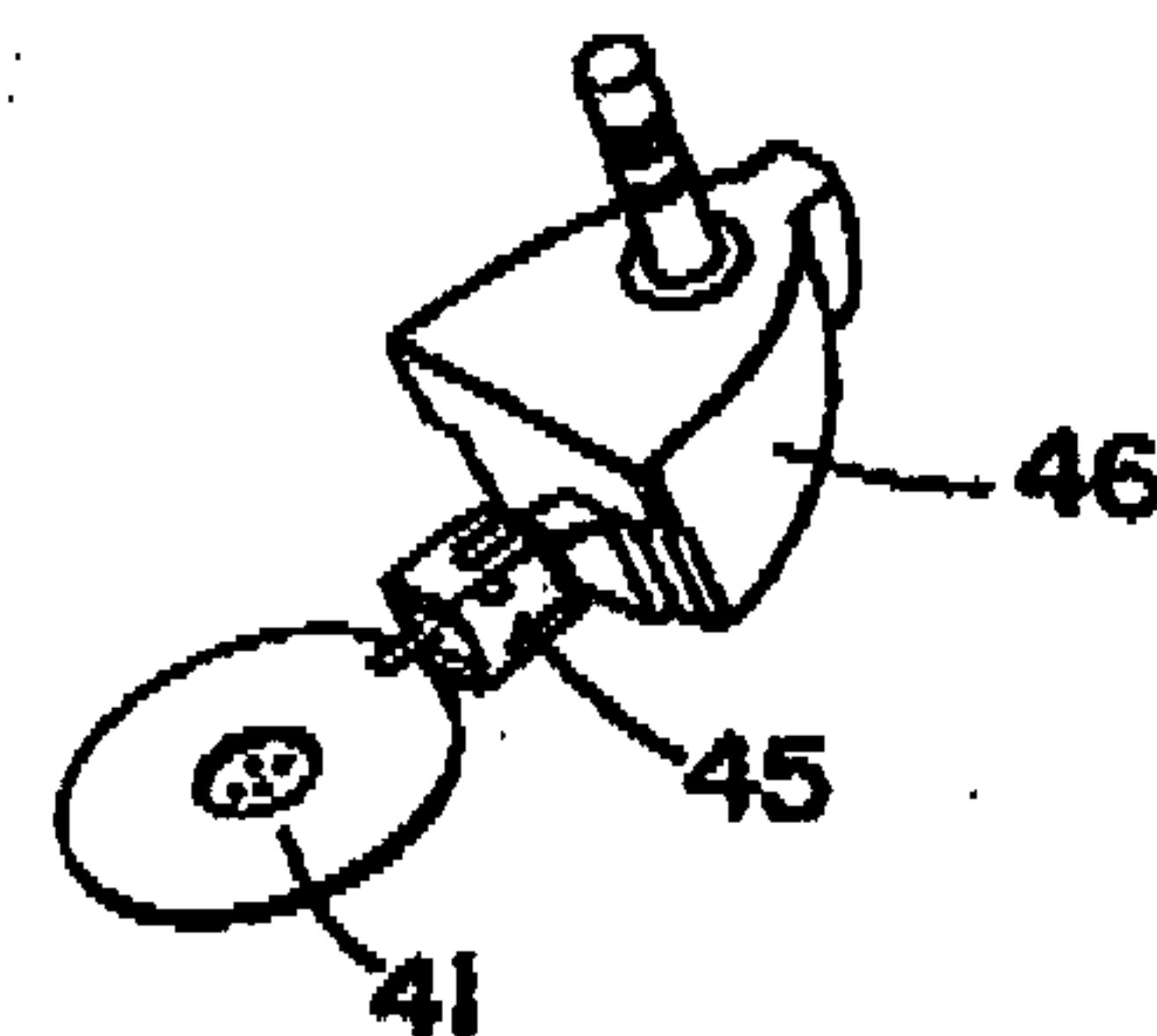


Fig. 9(b)

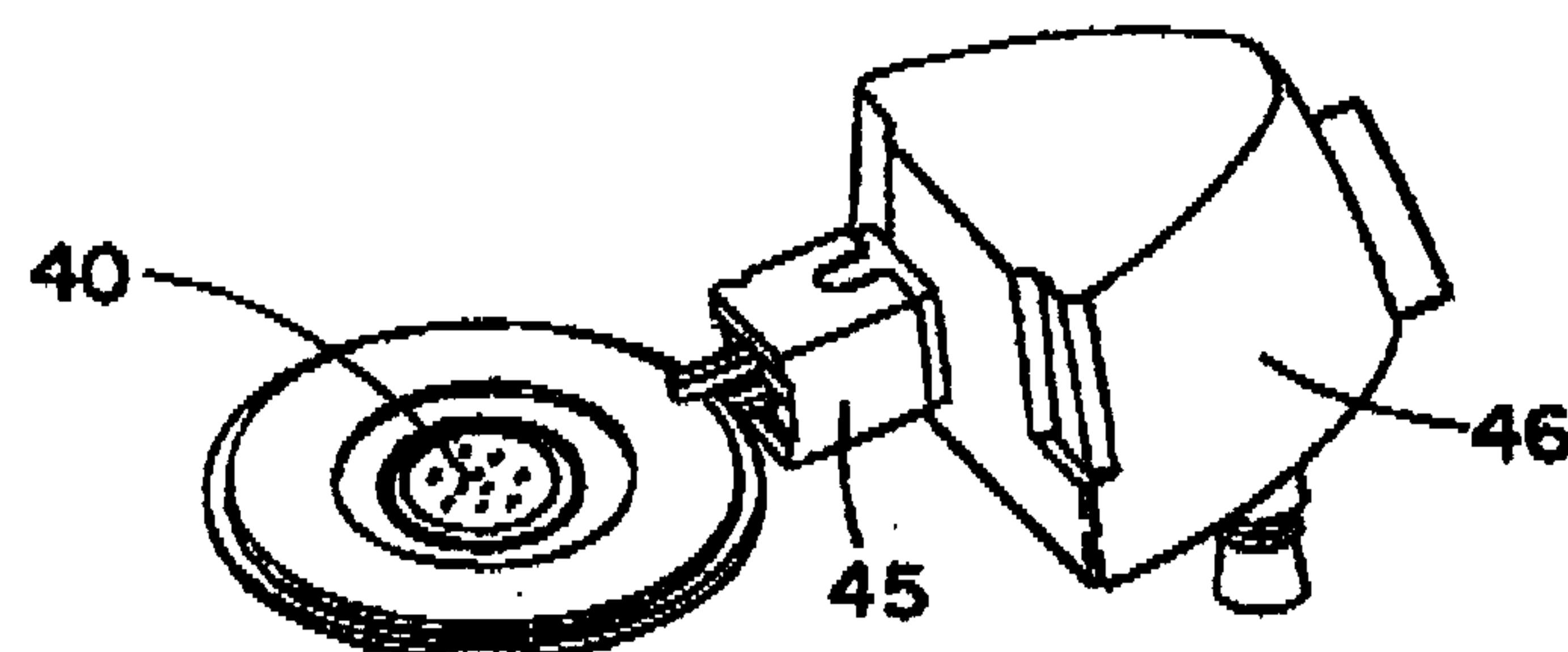
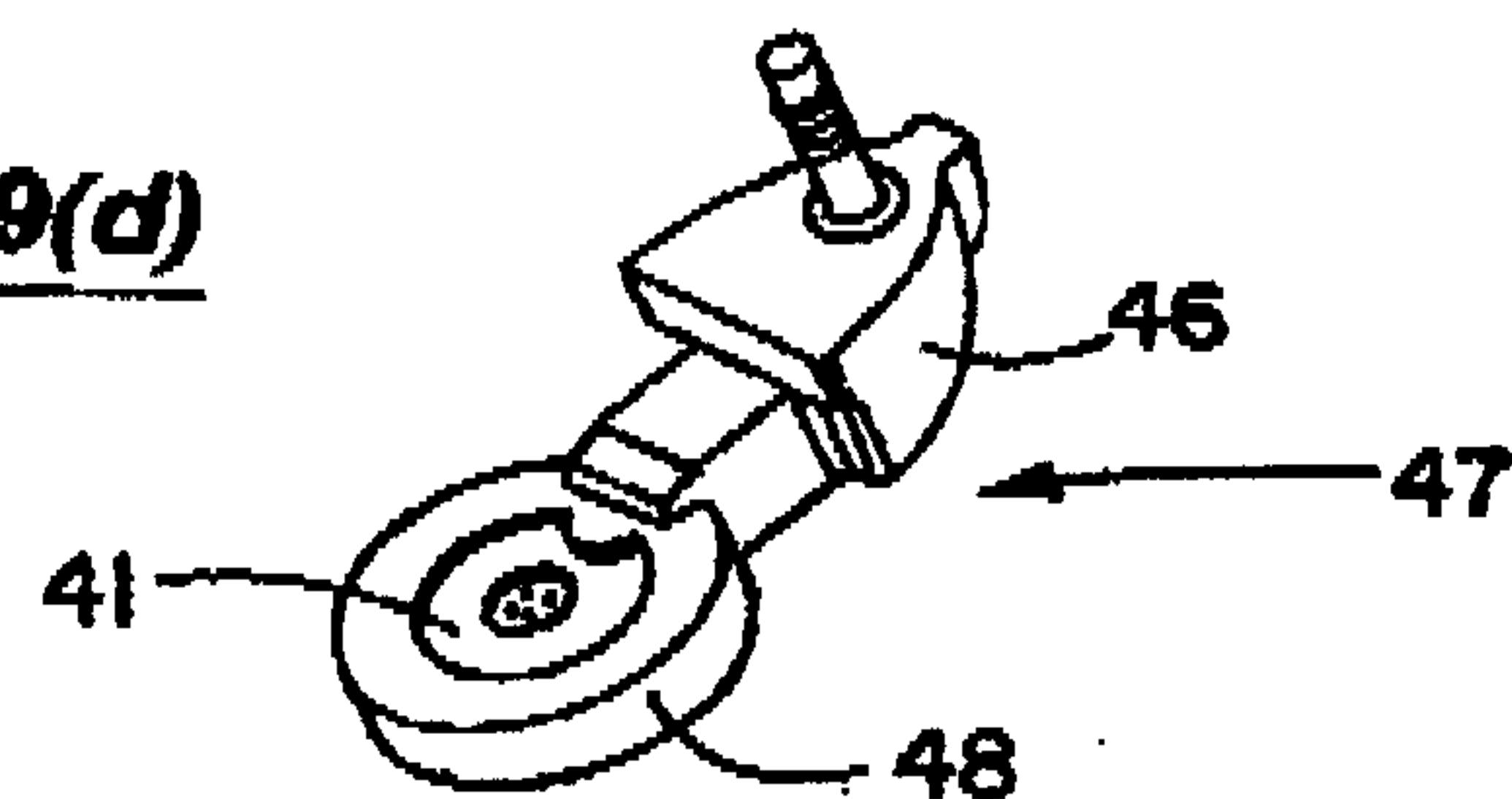
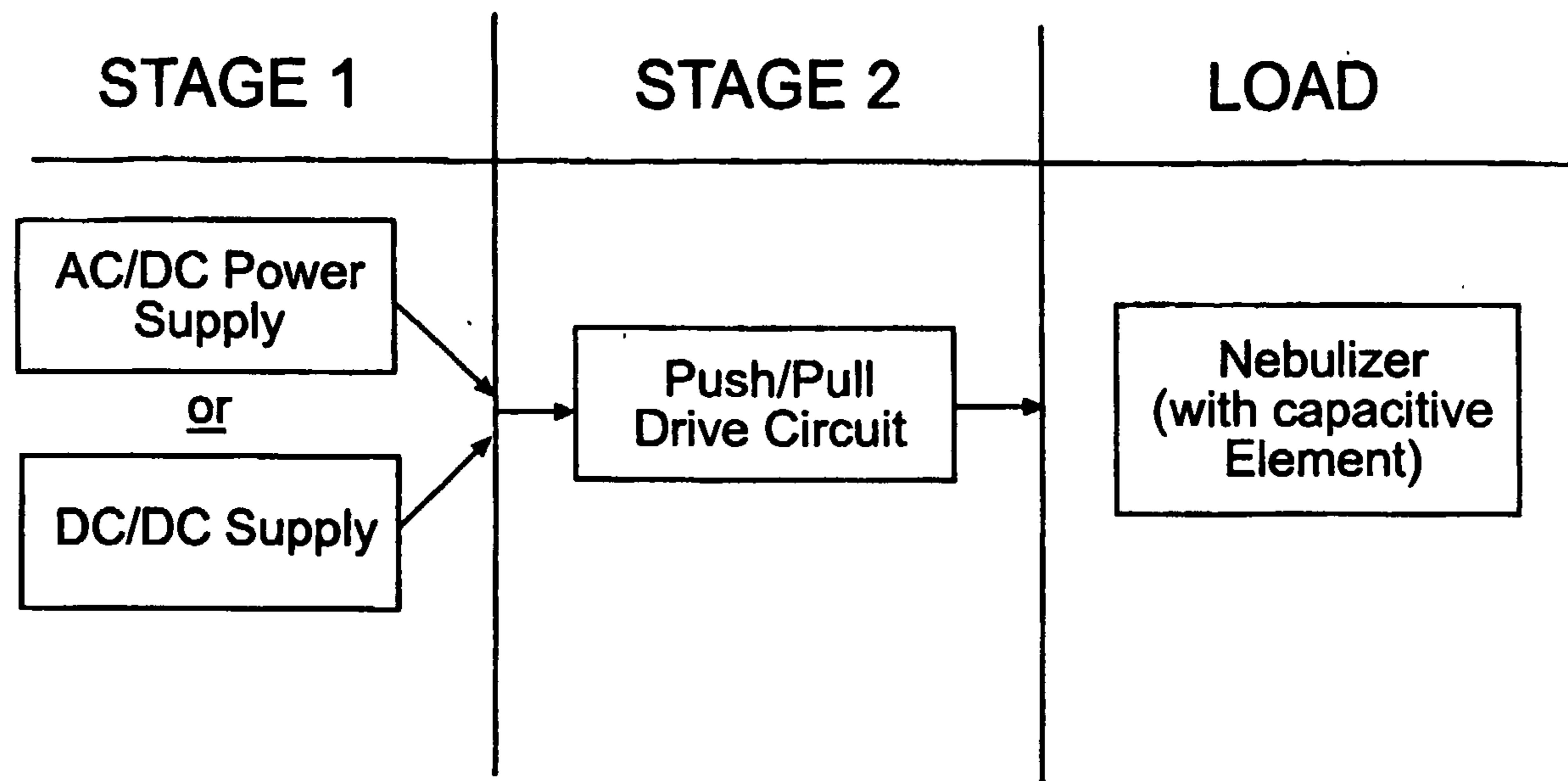
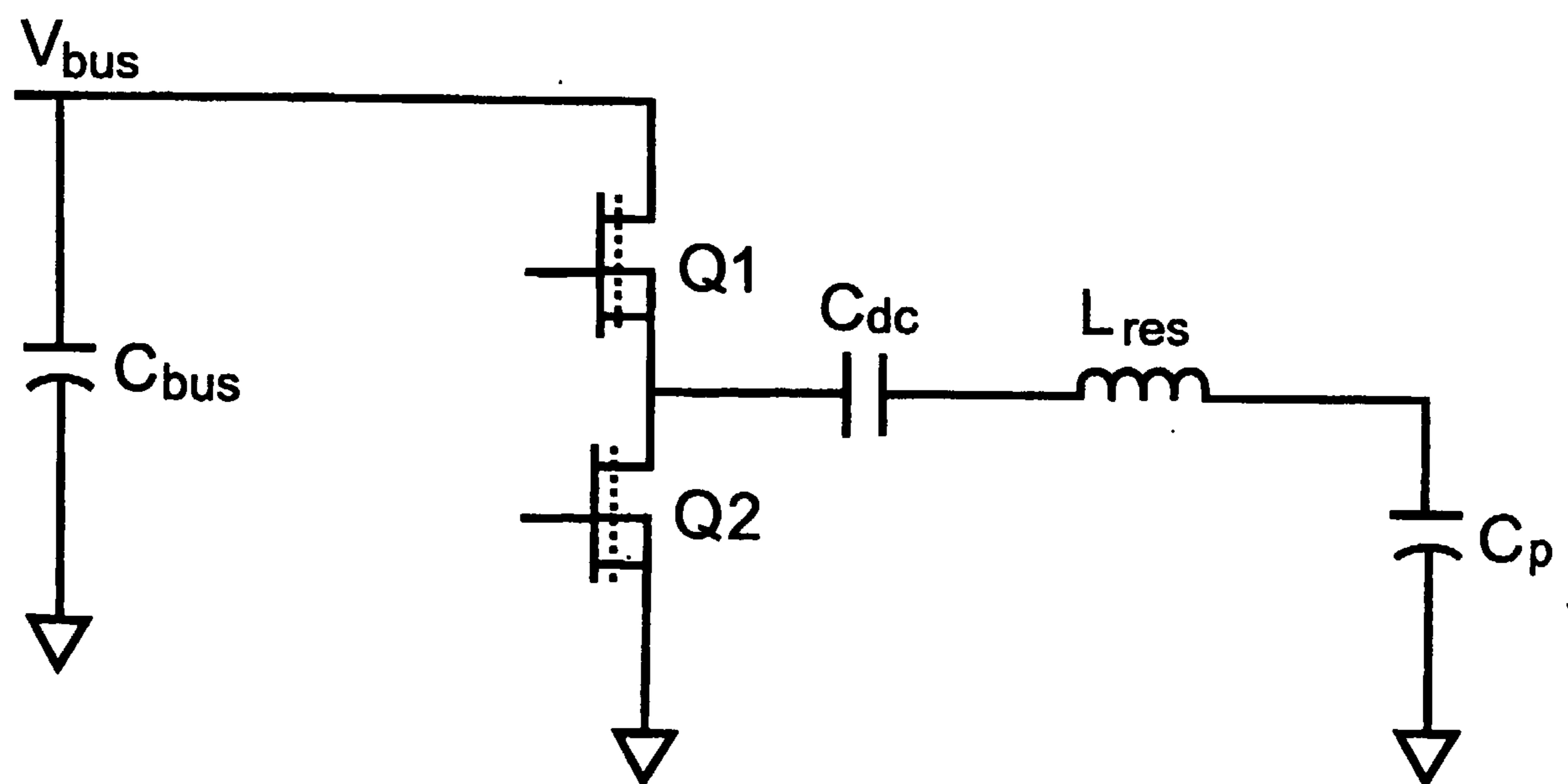


Fig. 9(c)

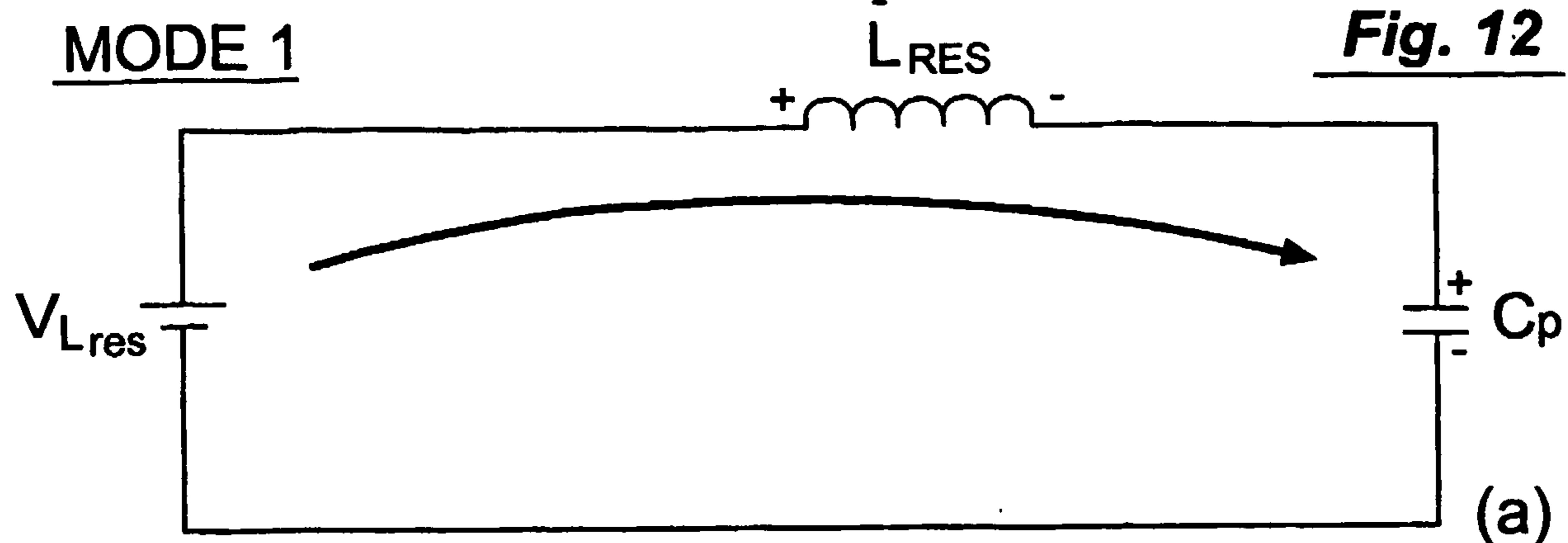
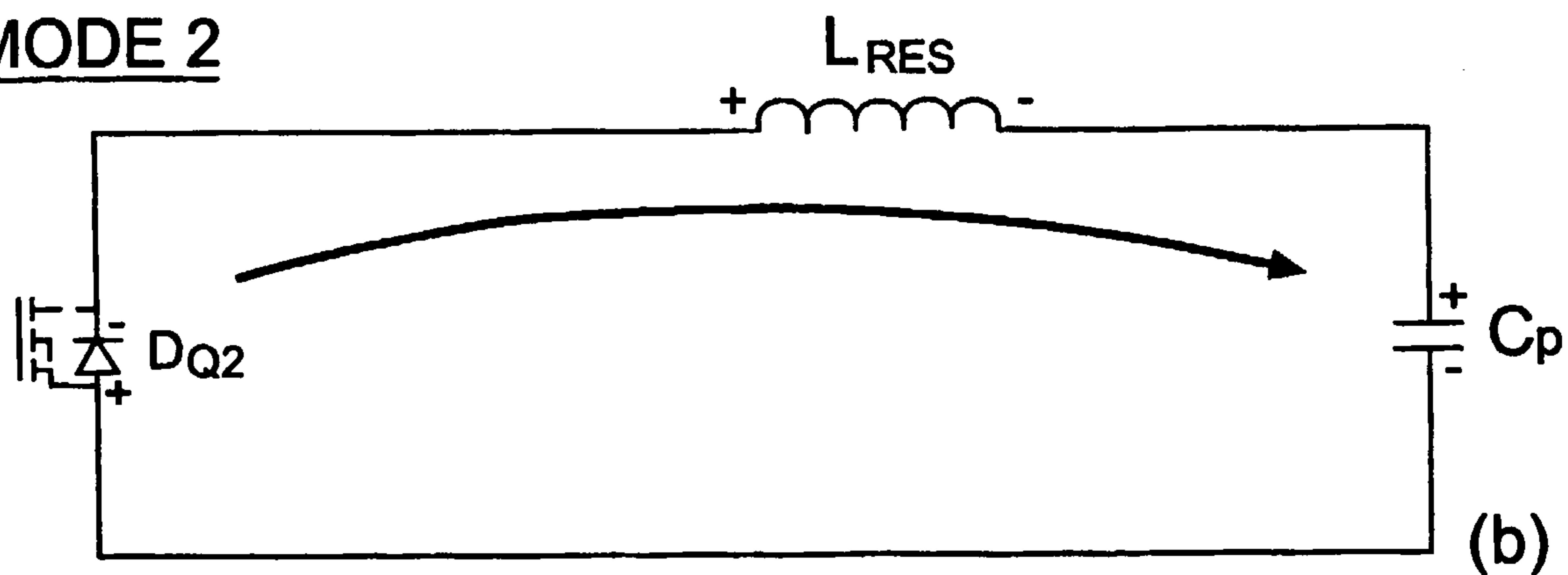
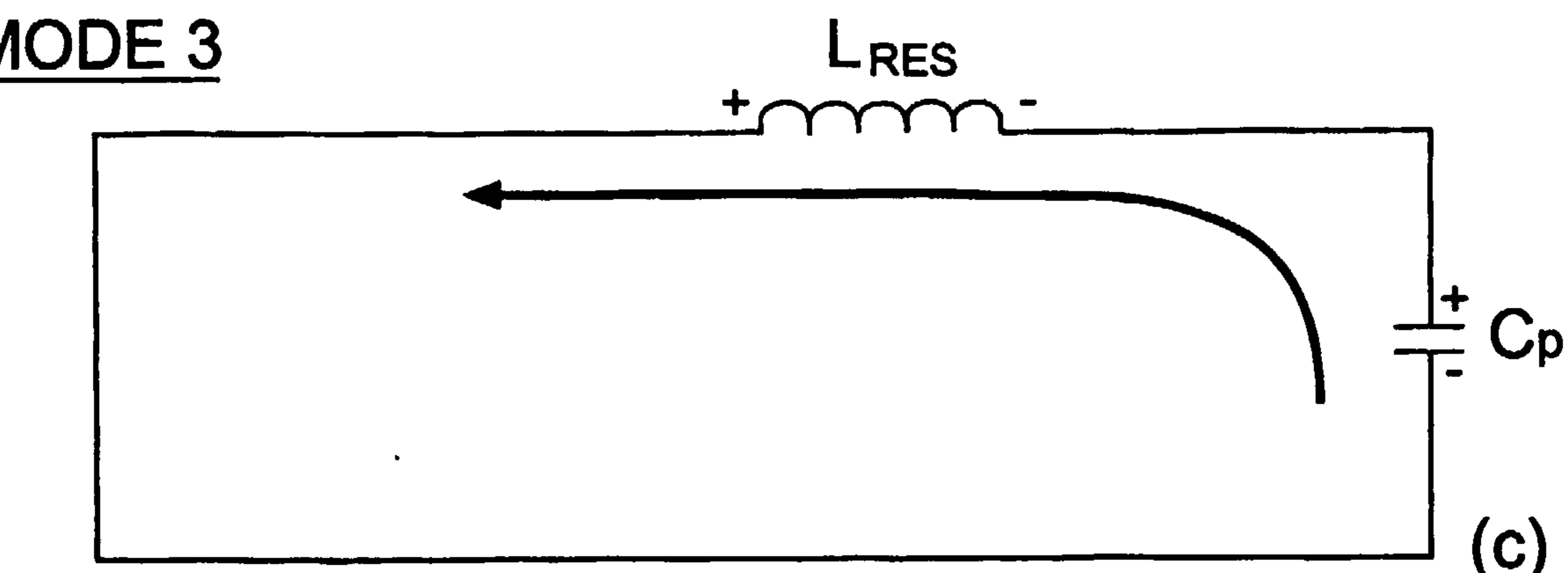
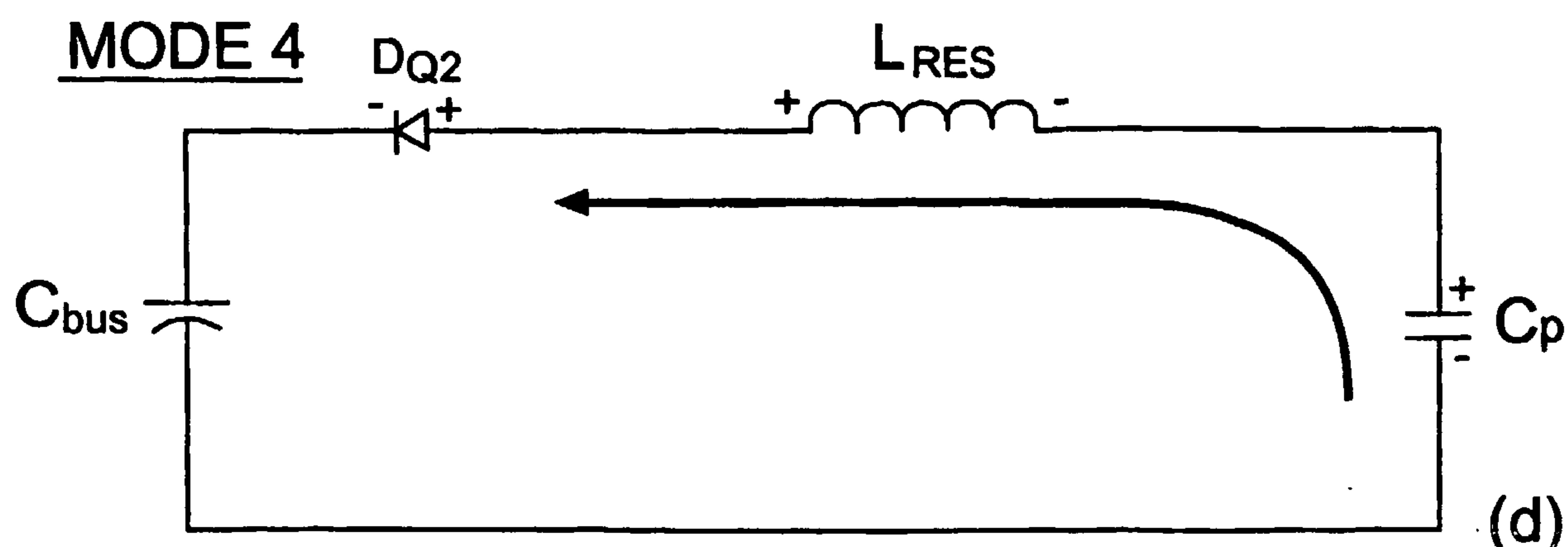
Fig. 9(d)



7/17

***Fig. 10******Fig. 11***

8/17

MODE 1Fig. 12MODE 2MODE 3MODE 4

9/17

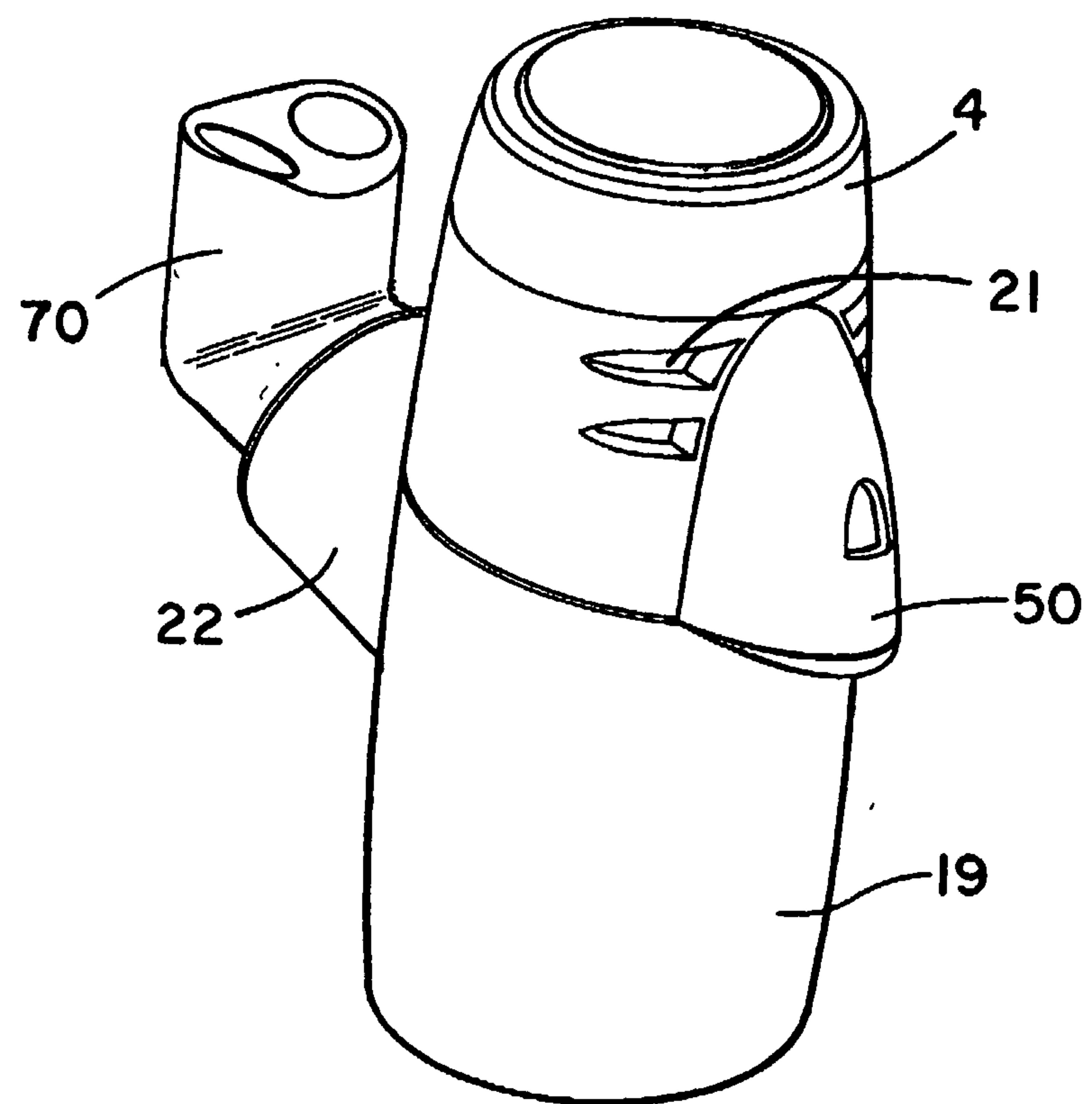


Fig. 13

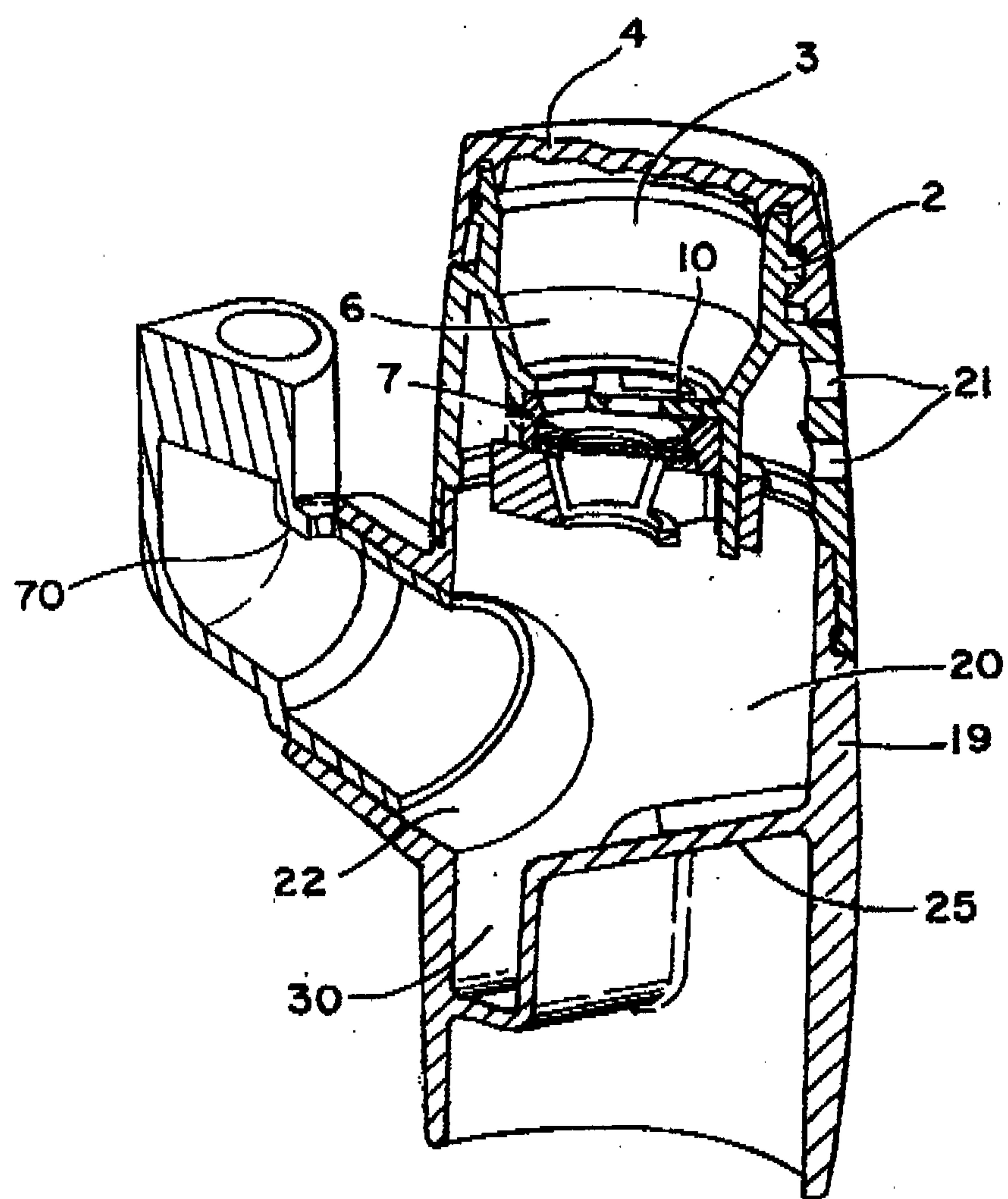
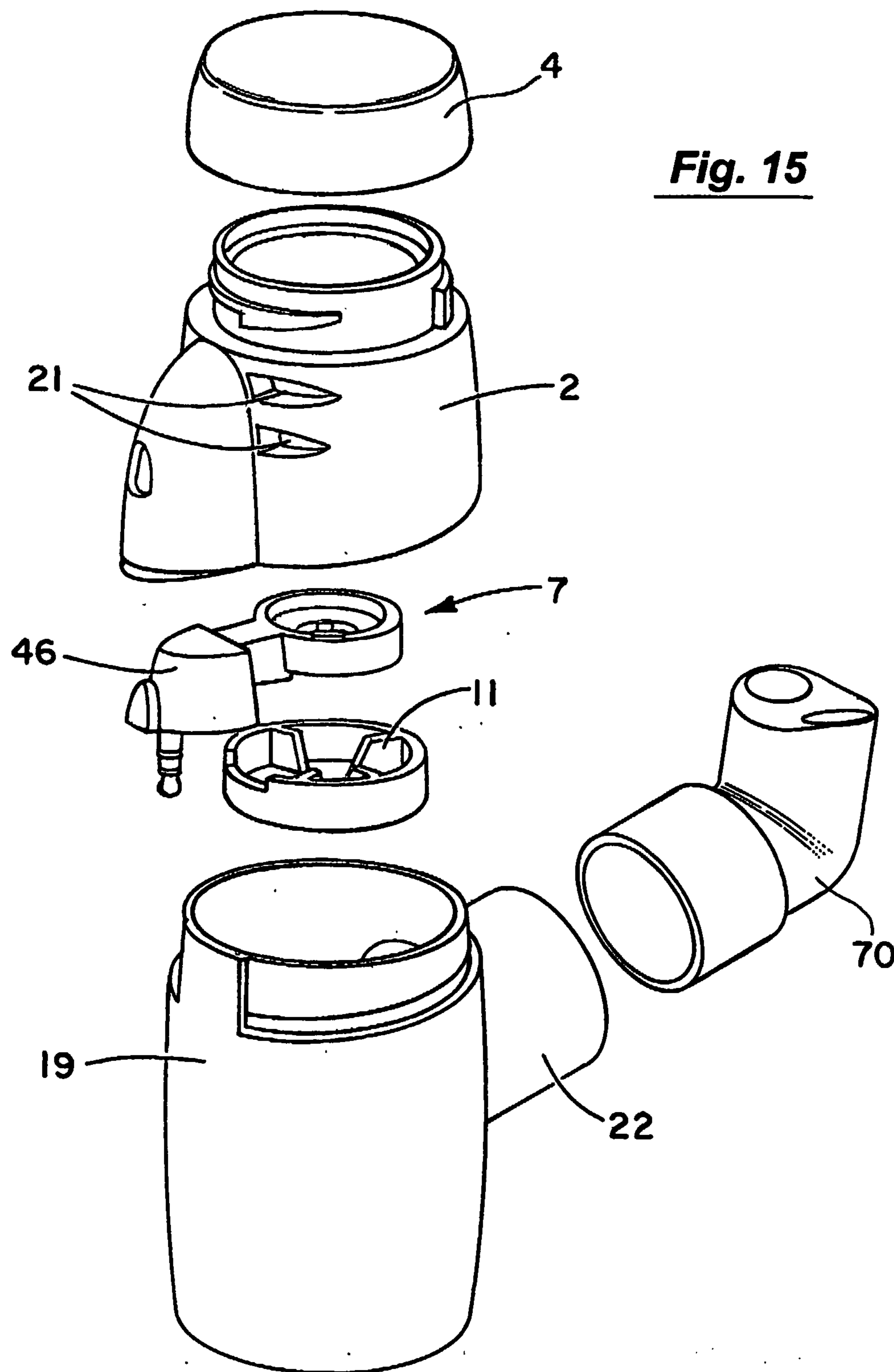
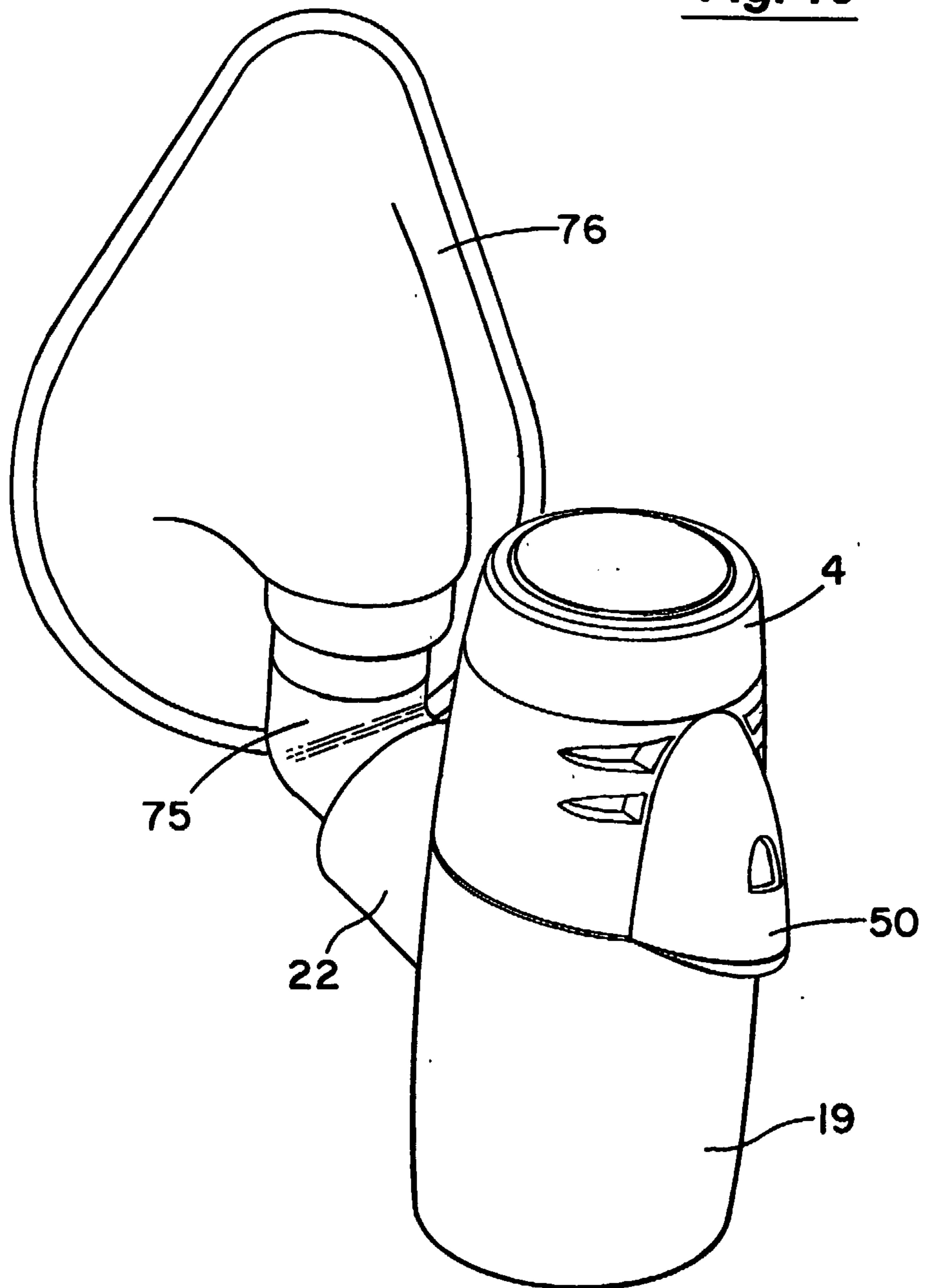


Fig. 14

11/17



12/17

Fig. 16

13/17

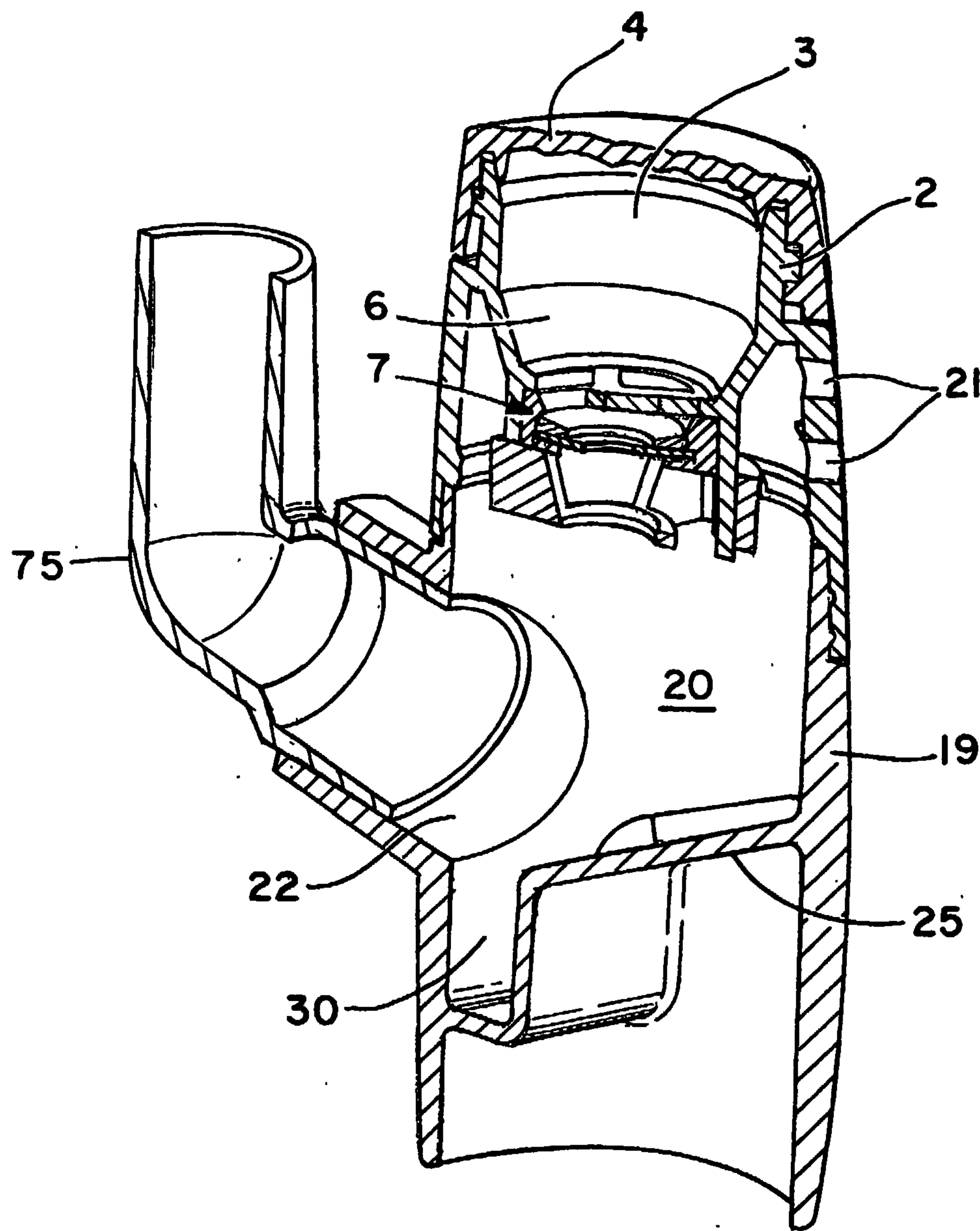


Fig. 17

14/17

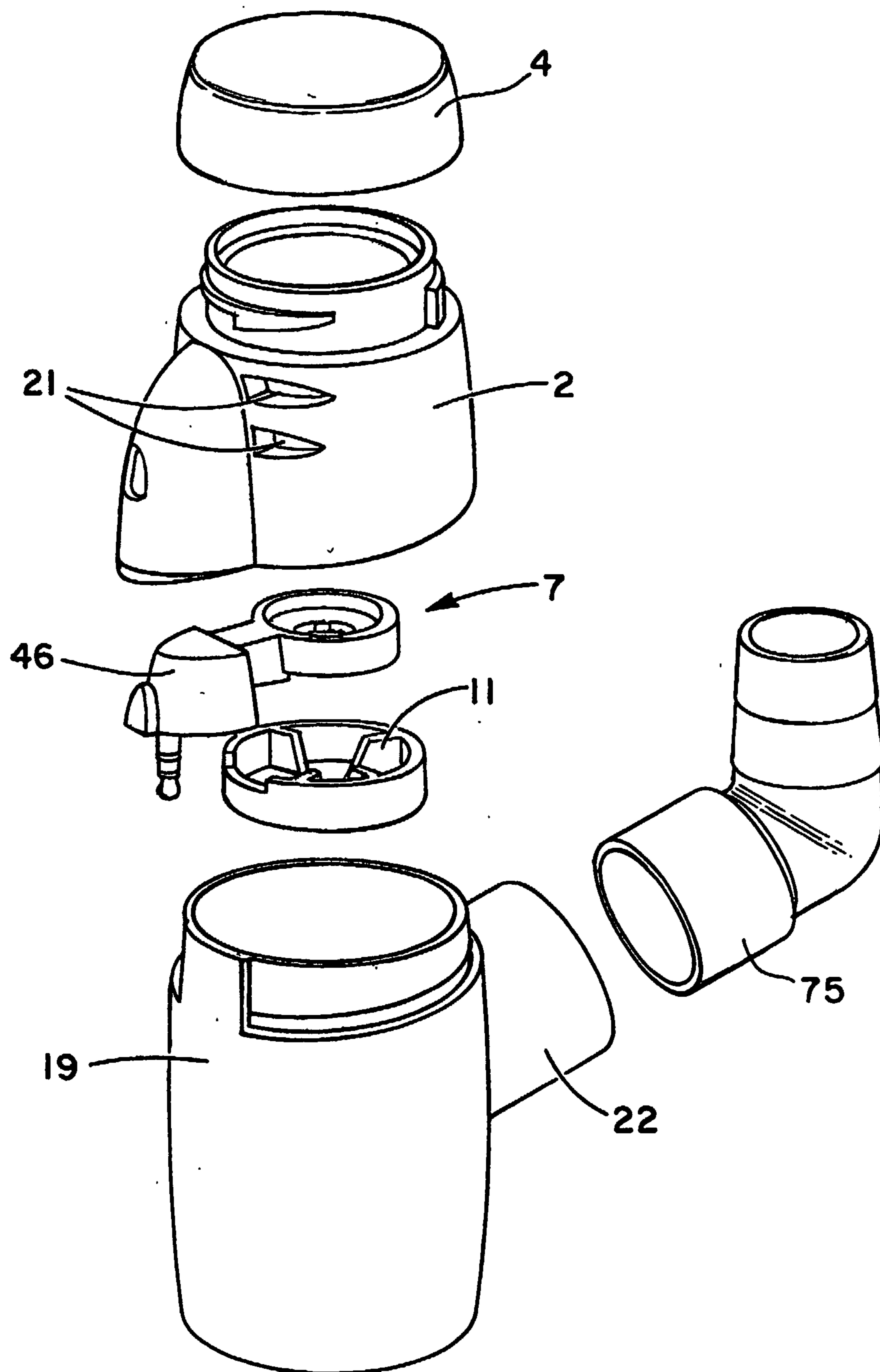


Fig 18

15/17

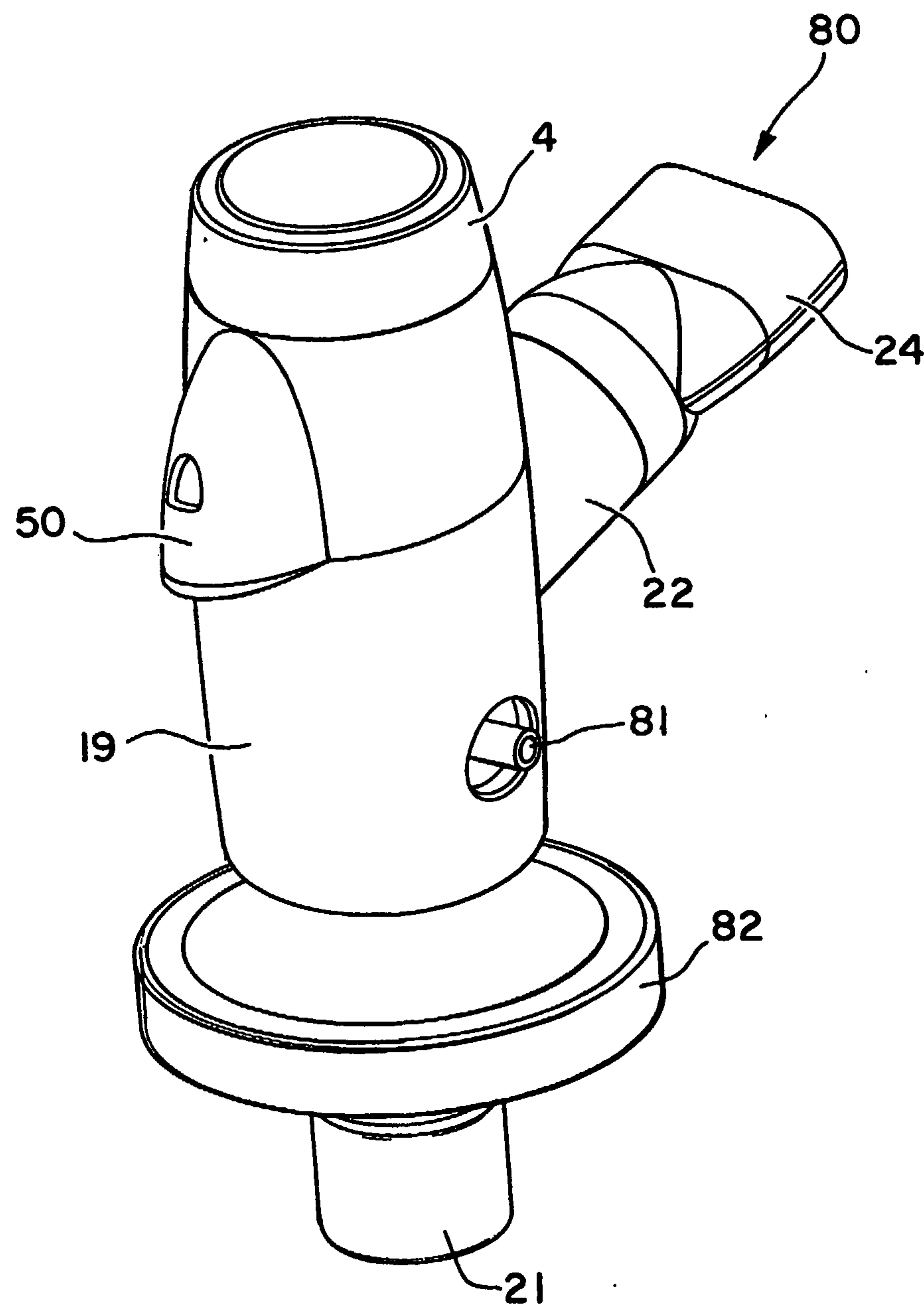


Fig. 19

16/17

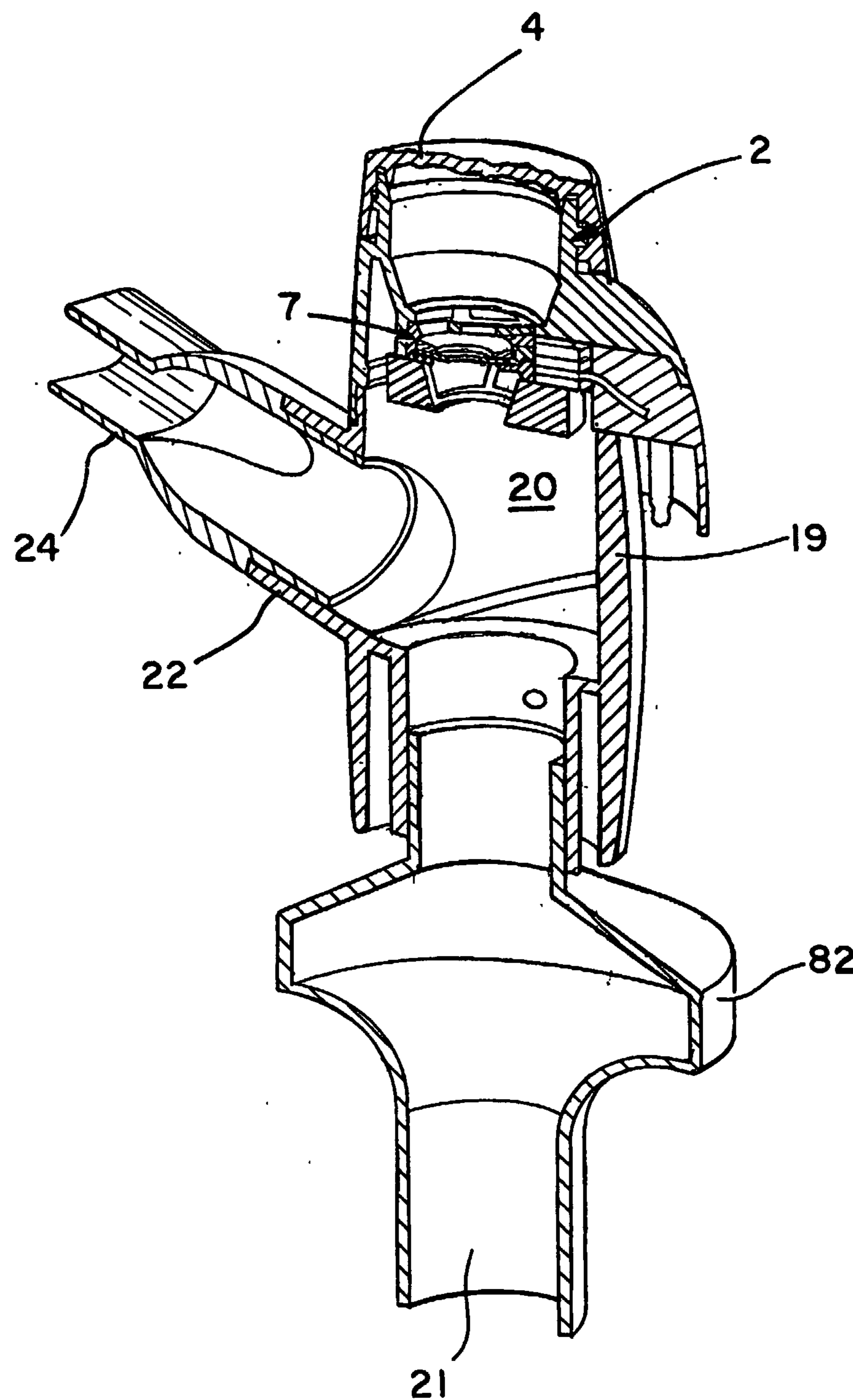


Fig. 20

17/17

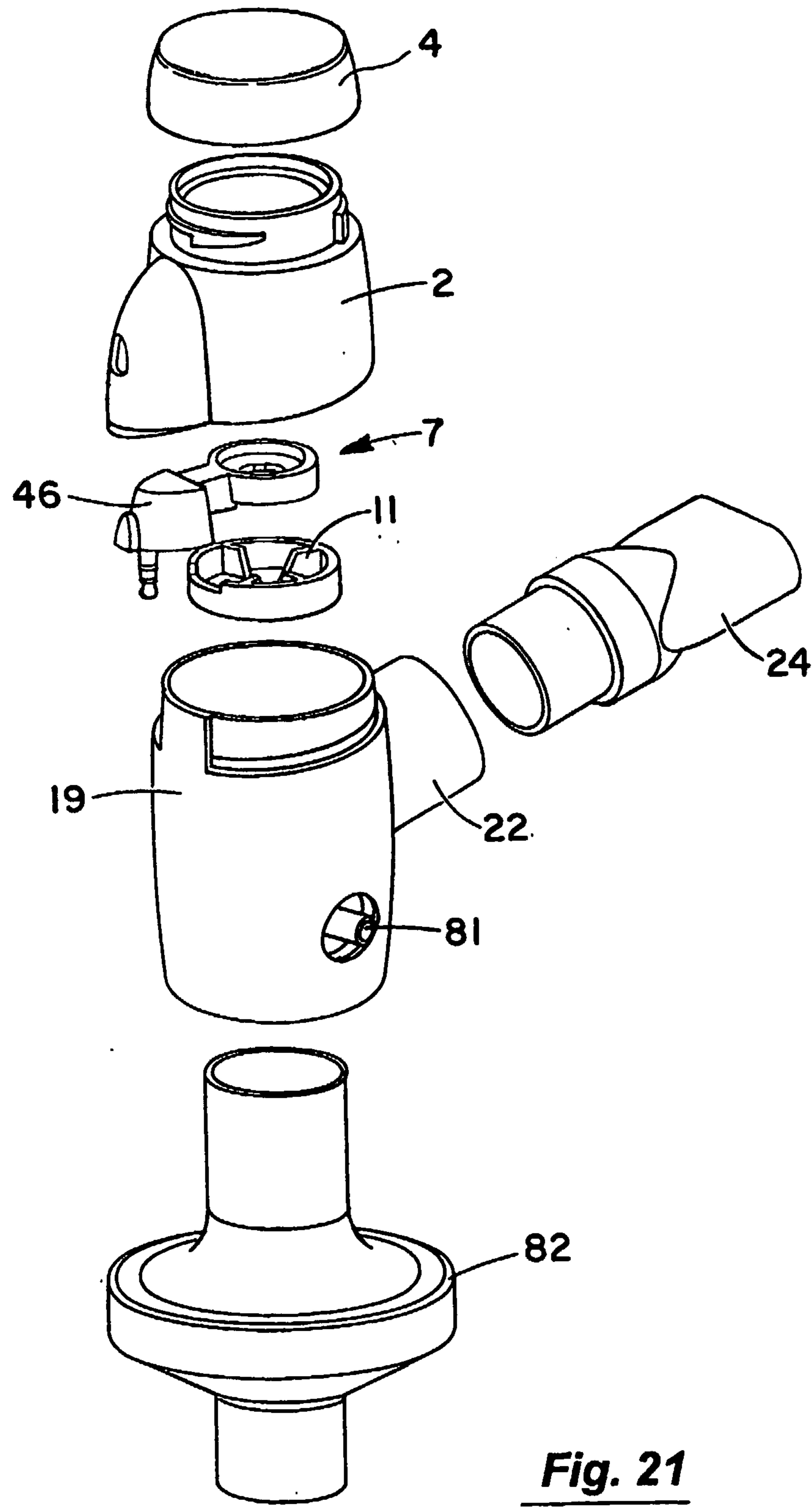


Fig. 21

