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(54) **MULTIPLE AIR CHAMBER FOAM PUMP**

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A47K 5/14 (2006.01)
B05B 7/00 (2006.01)

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CPC B05B 11/3087; B05B 11/3001; B05B 7/0037; B05B 11/3069; B05B 11/3074; B05B 7/005; B05B 7/0062; B05B 7/0056; B05B 7/2402; B05B 7/2408; B05B 11/00; A47K 5/14
USPC 222/145.5–145.6, 190, 132–137, 129, 222/180, 181.2, 325, 321.7–321.9
See application file for complete search history.

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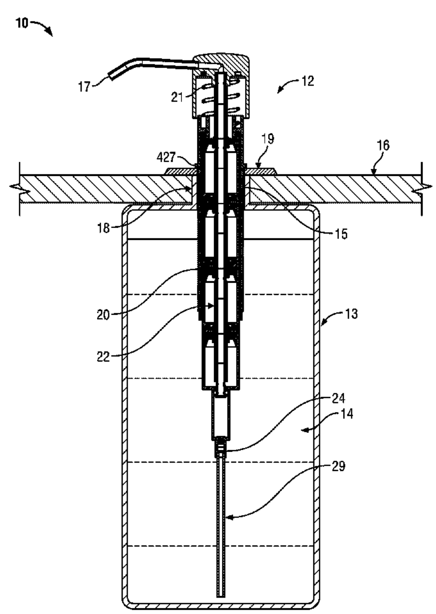
(57) **ABSTRACT**

An improved foam piston pump in which a multiple of air pumps are disposed coaxially about a piston member and spaced axially along the piston member, preferably coaxially with a liquid pump for discharging air and liquid as foam. Each air pump is preferably provided by a modular piston within a modular casing assembly such that arrangements with one, two or more identical air pumps can be assembled from a plurality of the same modular components.

11 Claims, 17 Drawing Sheets



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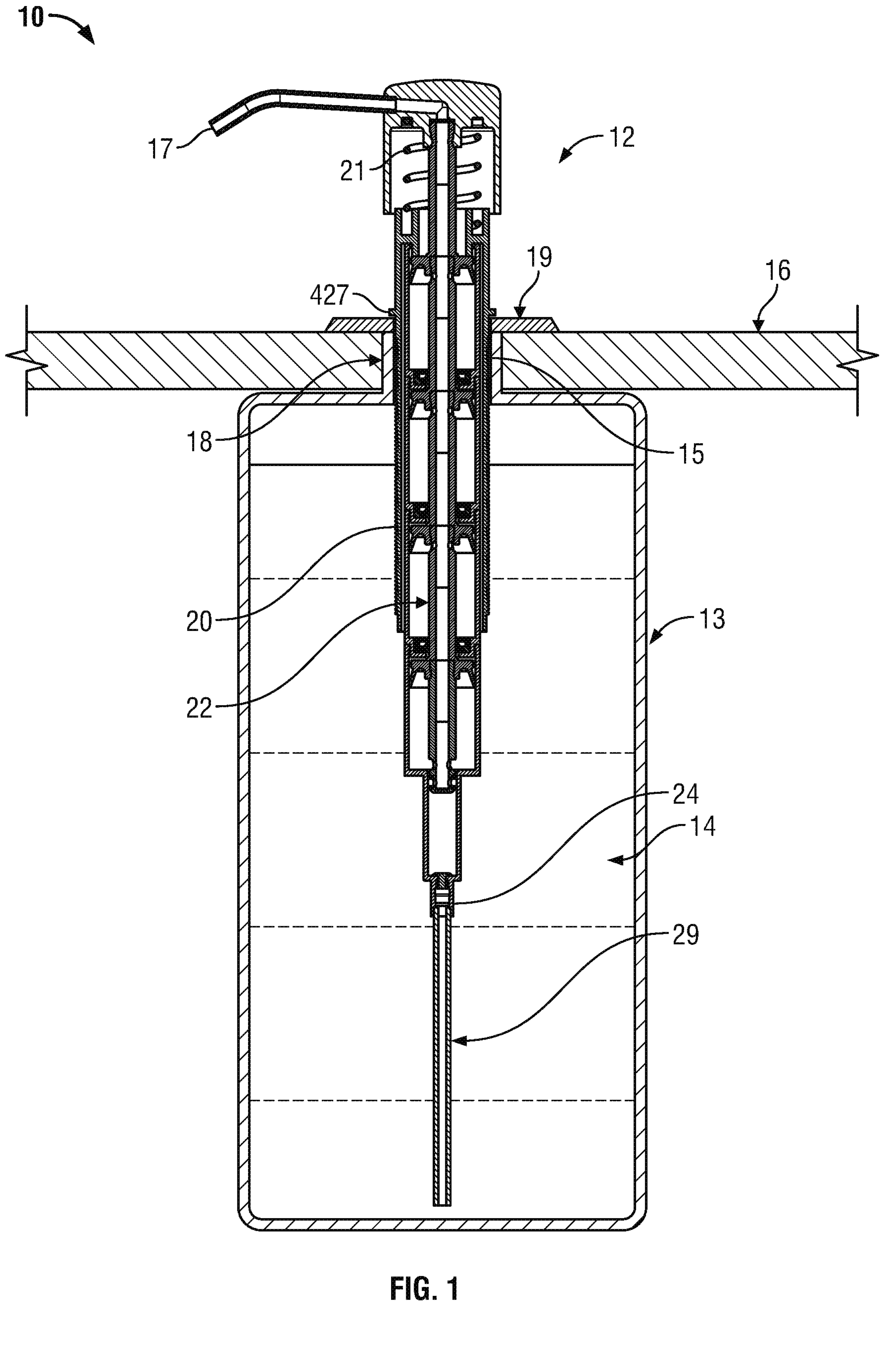

FIG. 1

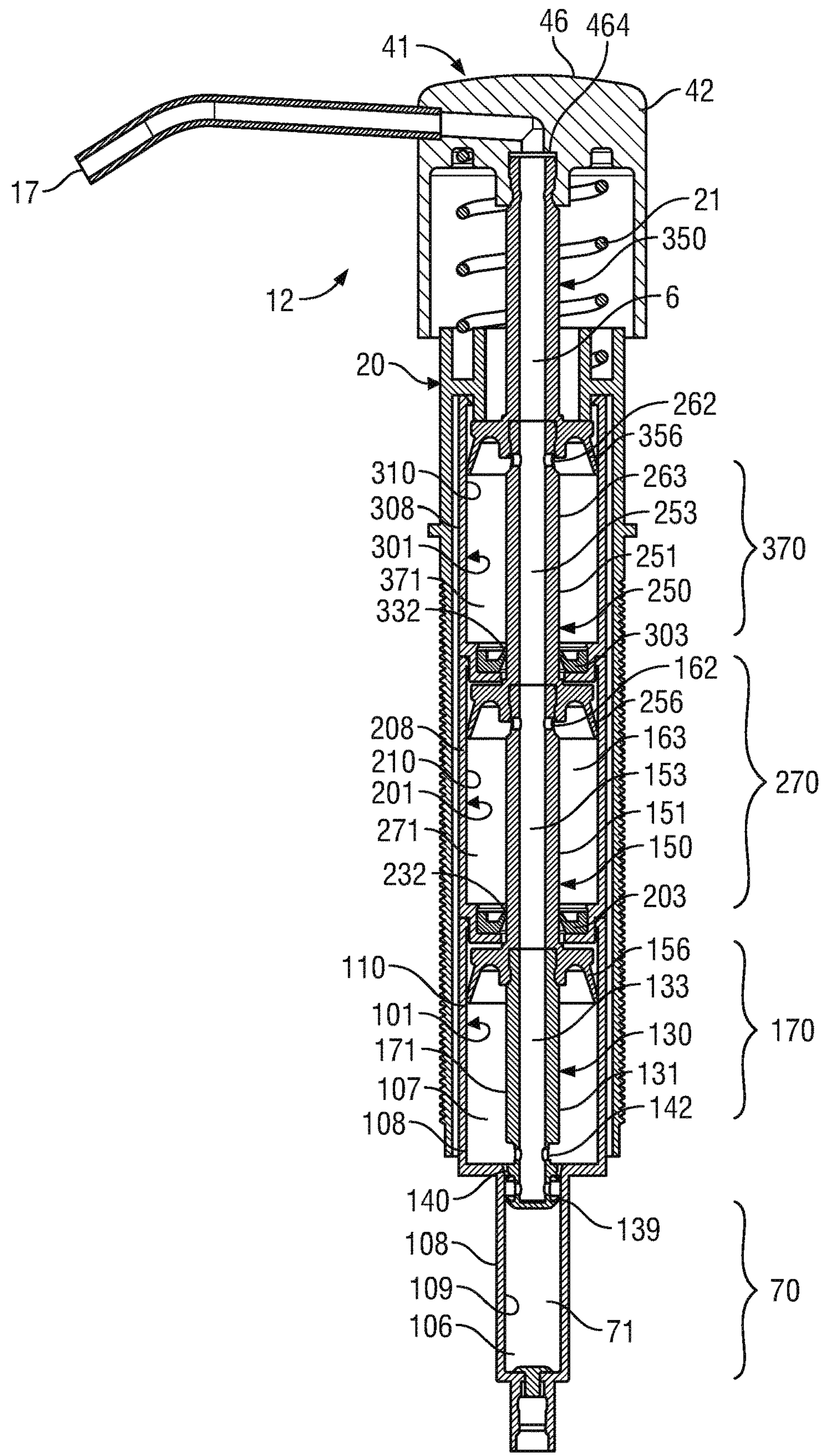
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FIG. 2

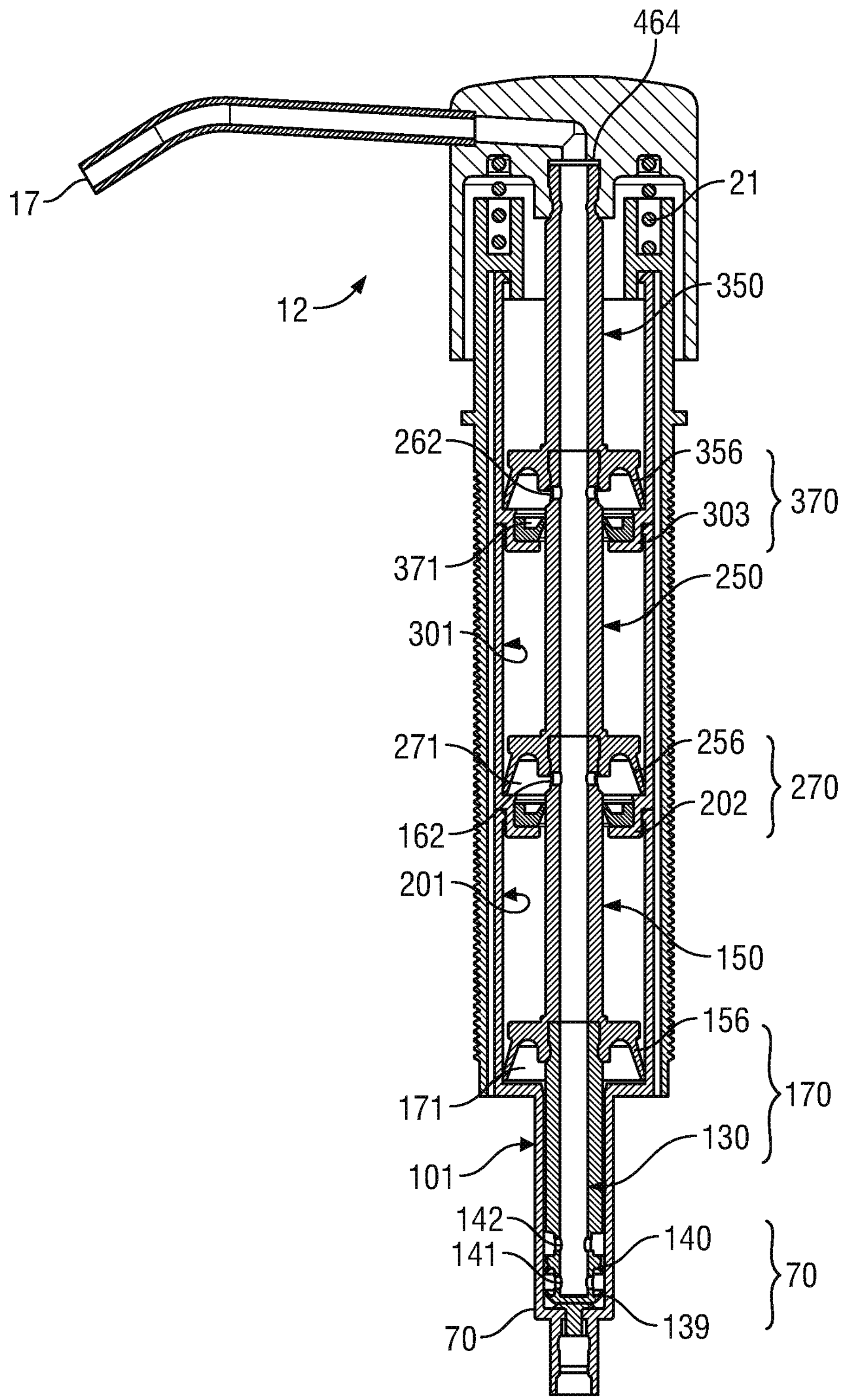
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FIG. 3

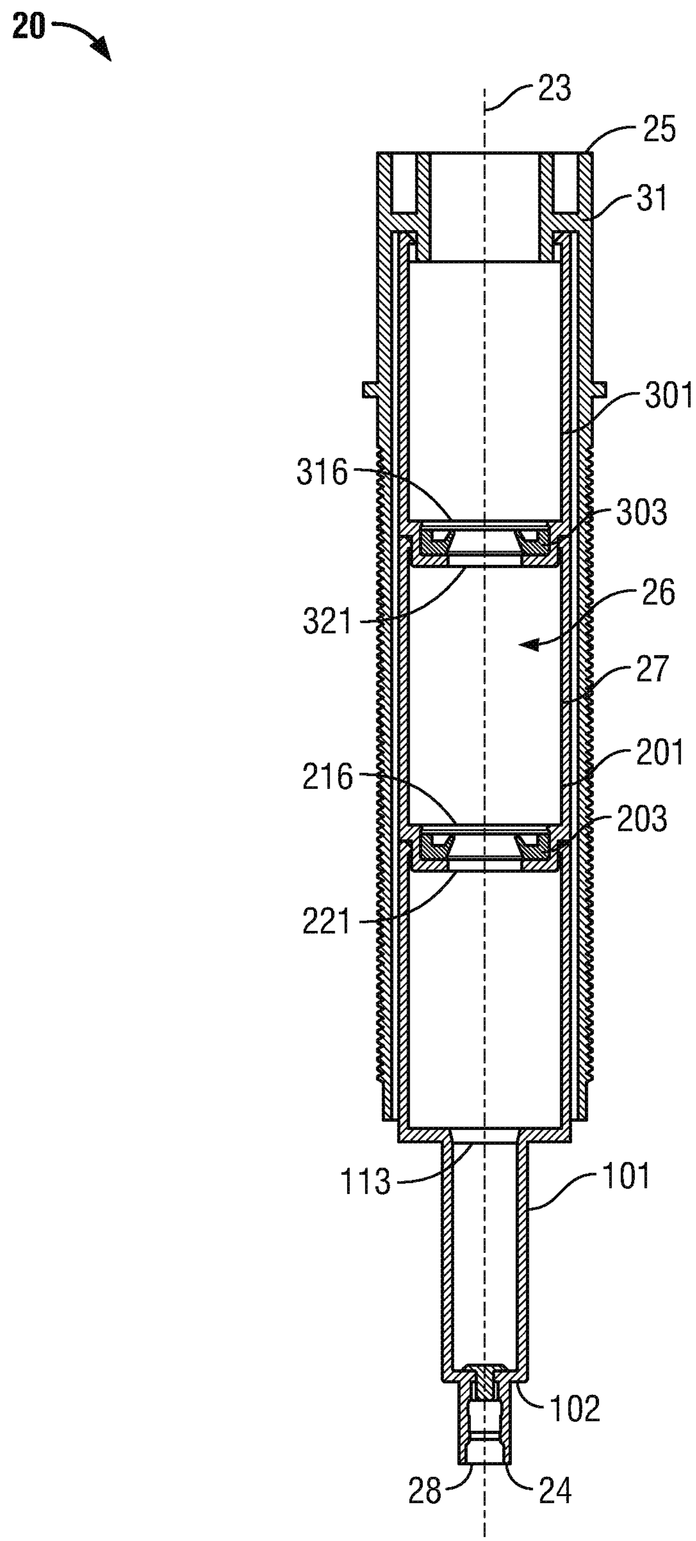

FIG. 4

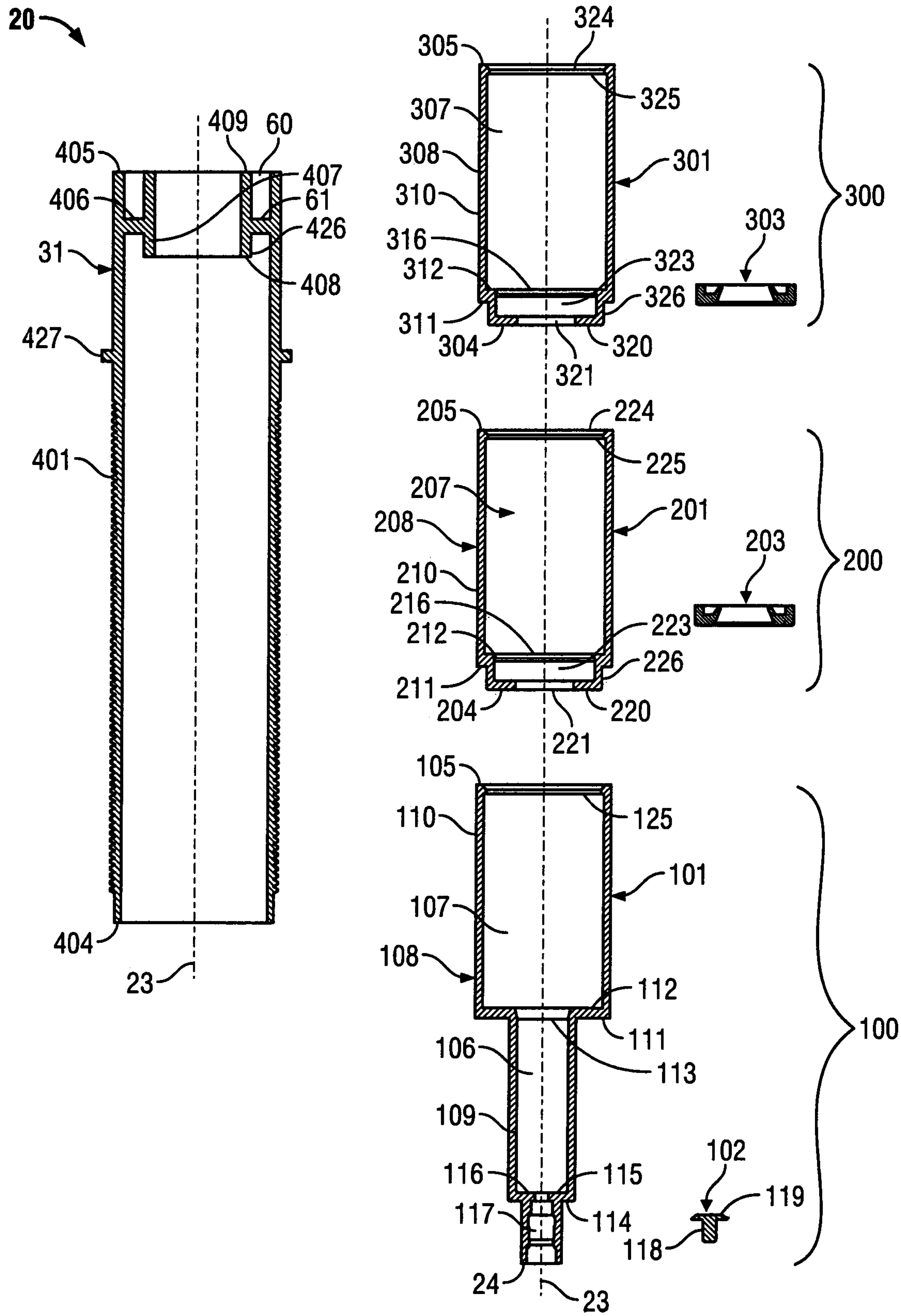

FIG. 5 AMENDED

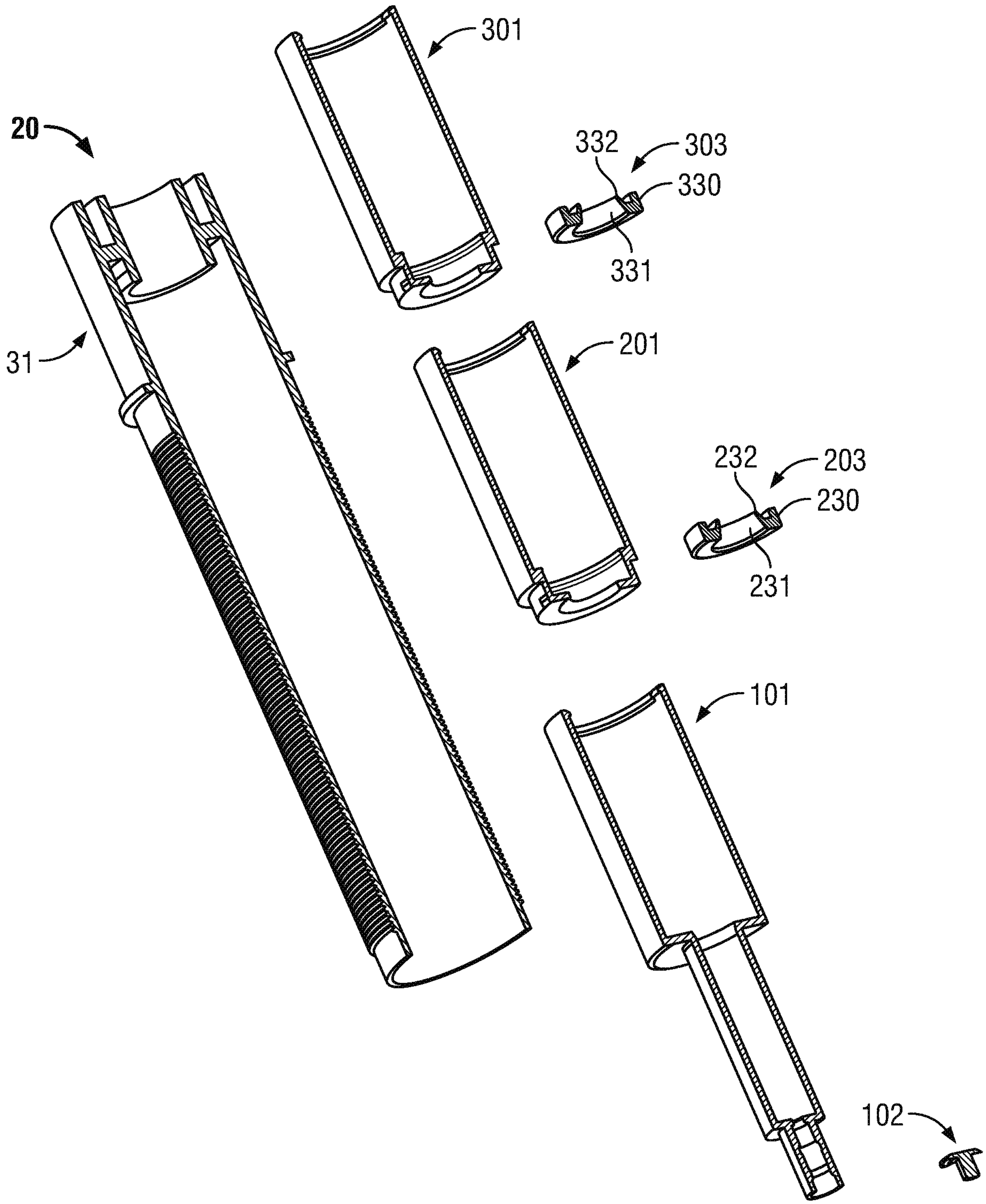

FIG. 6

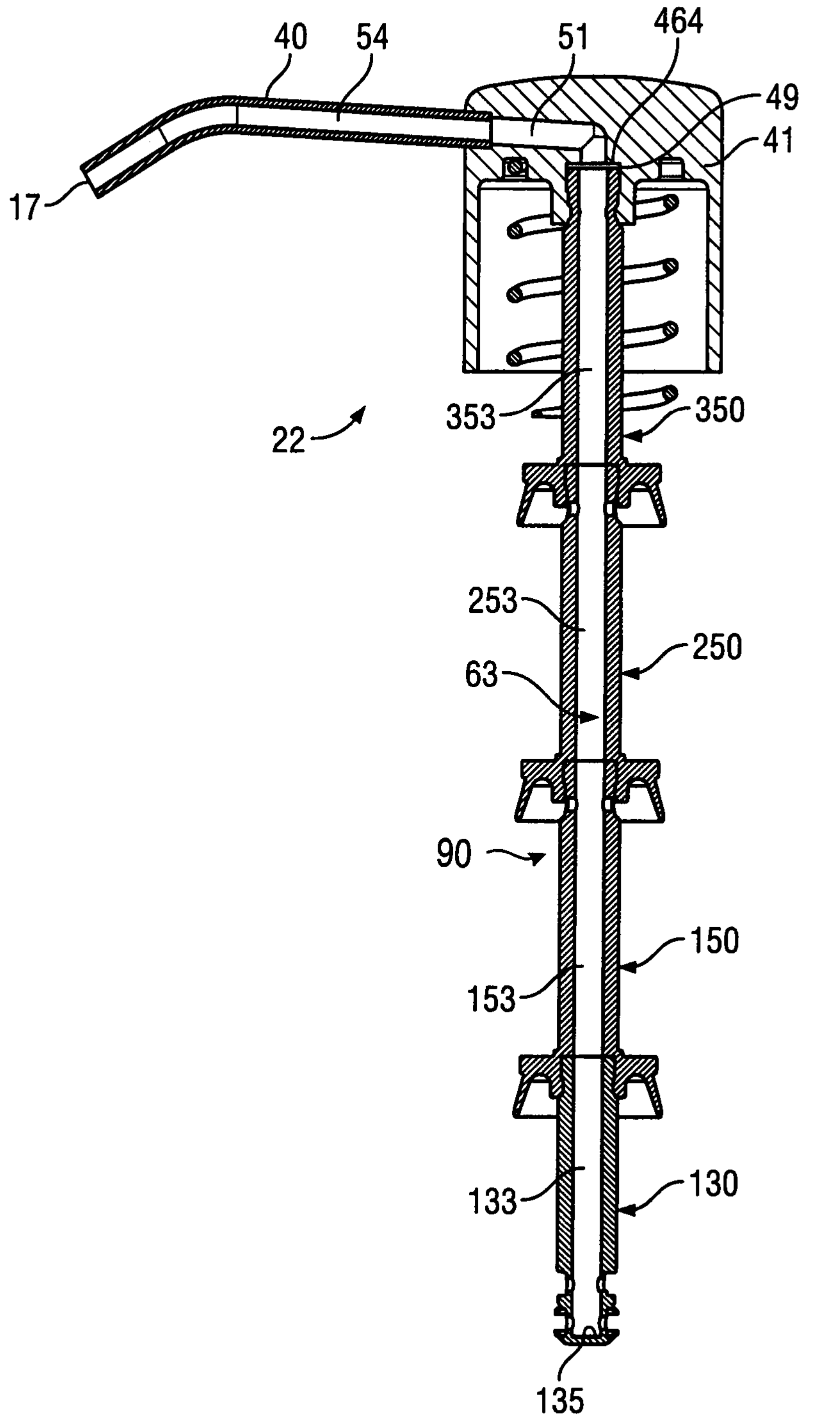

FIG. 7 AMENDED

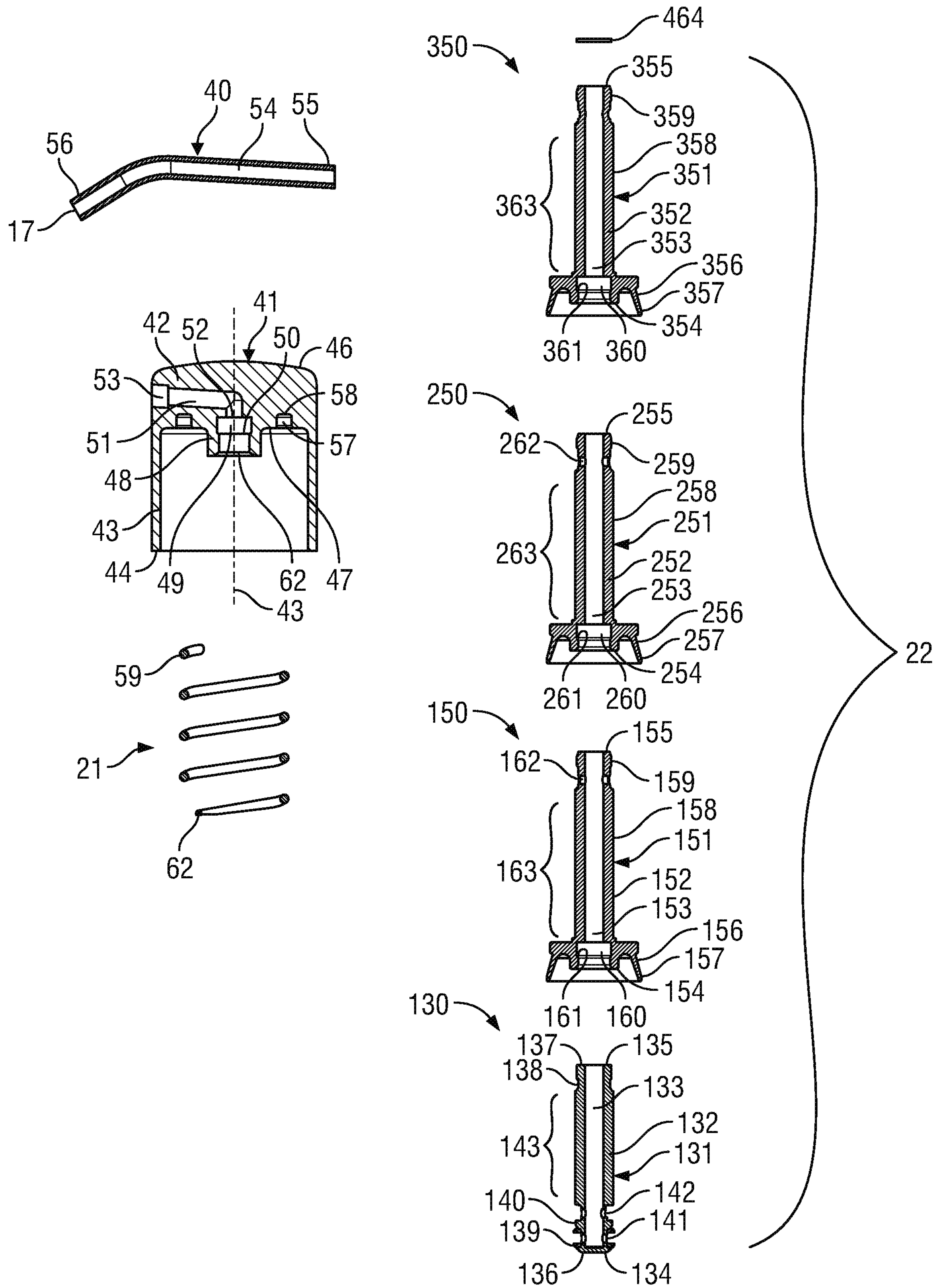

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FIG. 8

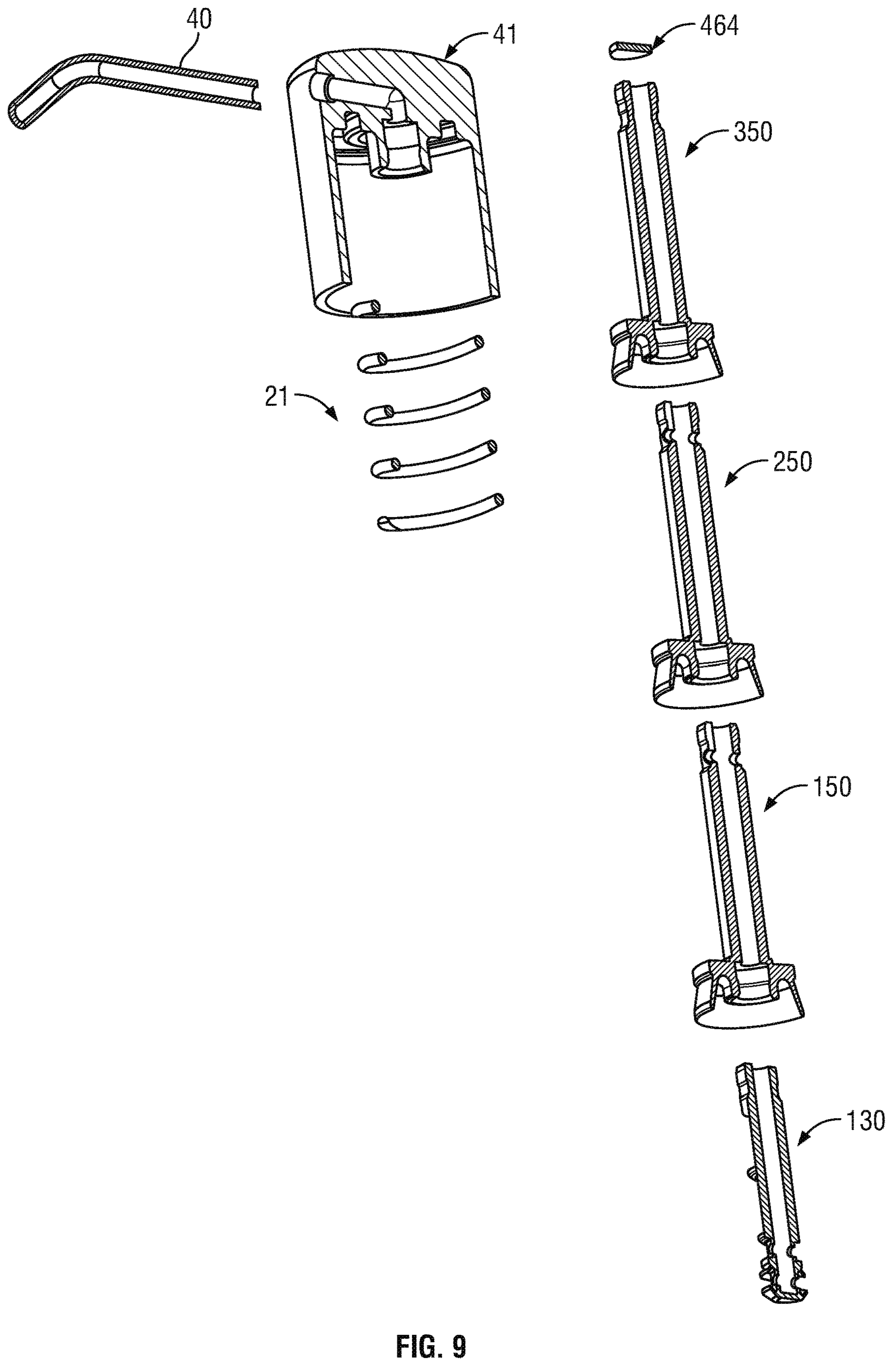

FIG. 9

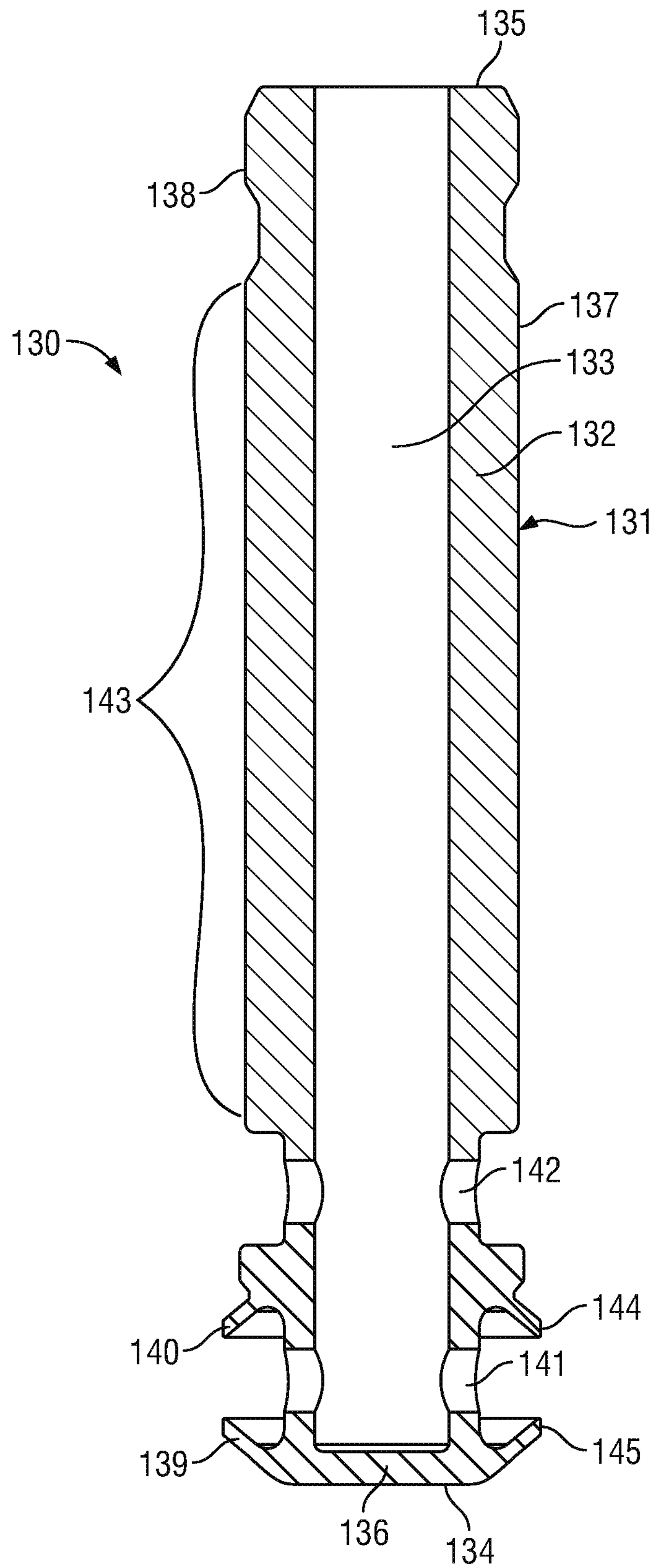

FIG. 10

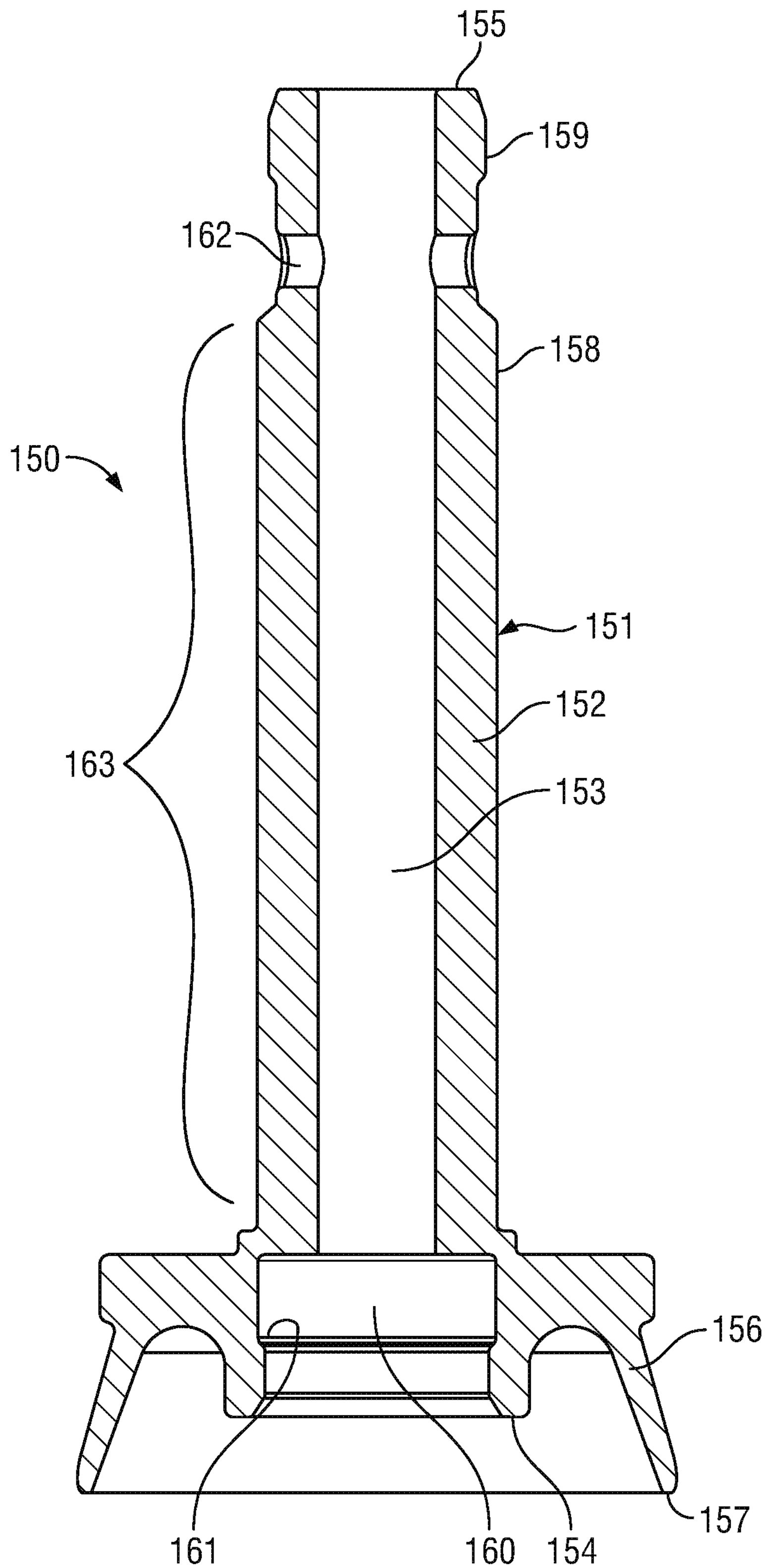

FIG. 11

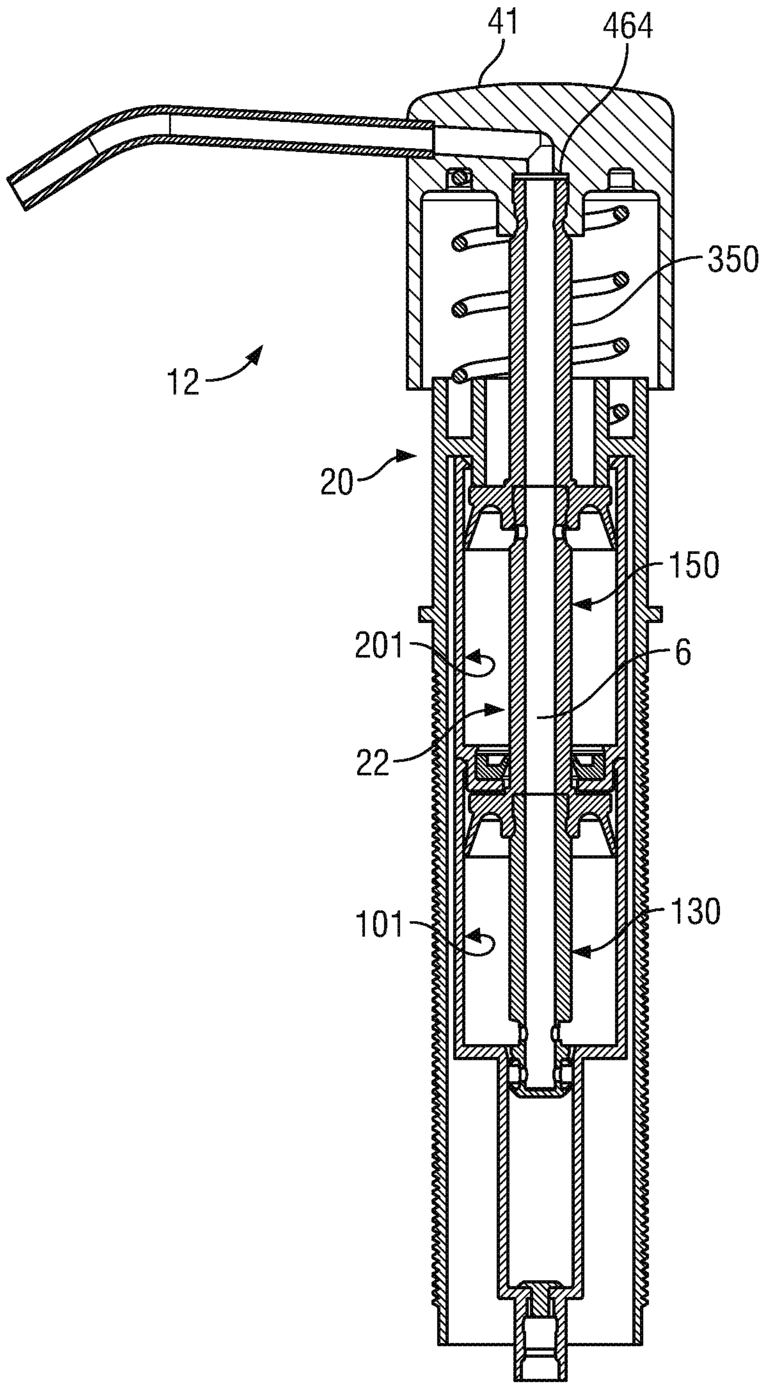

FIG. 12

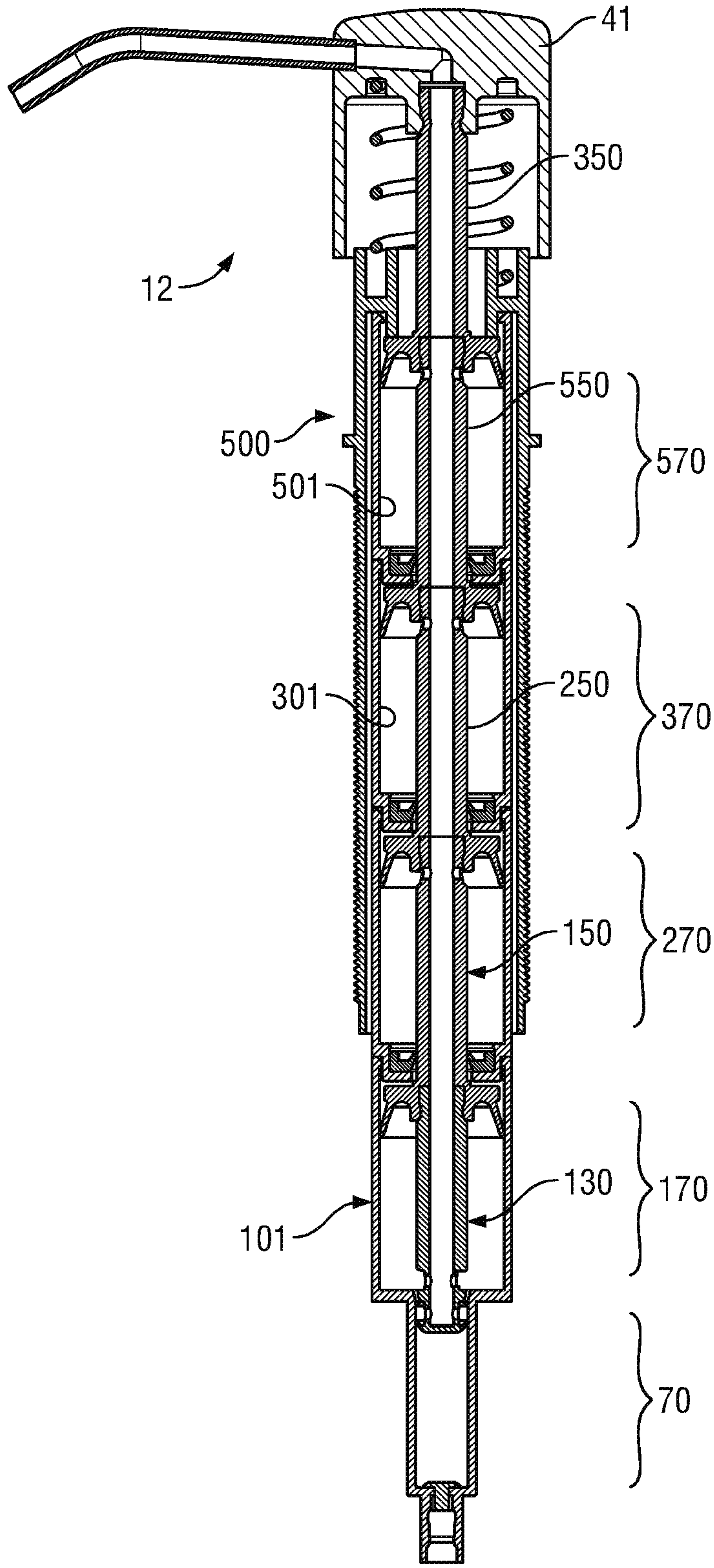

FIG. 13

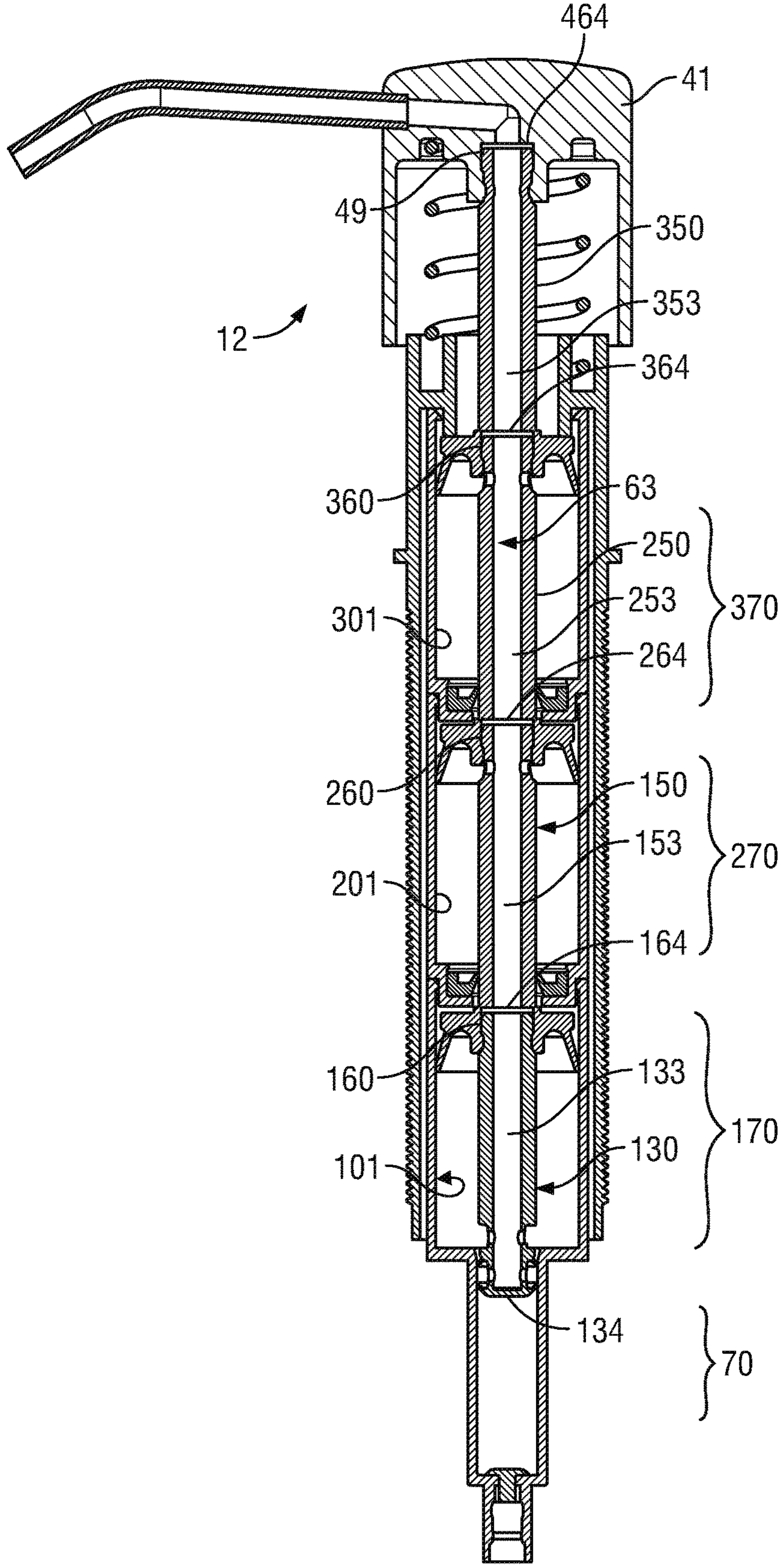
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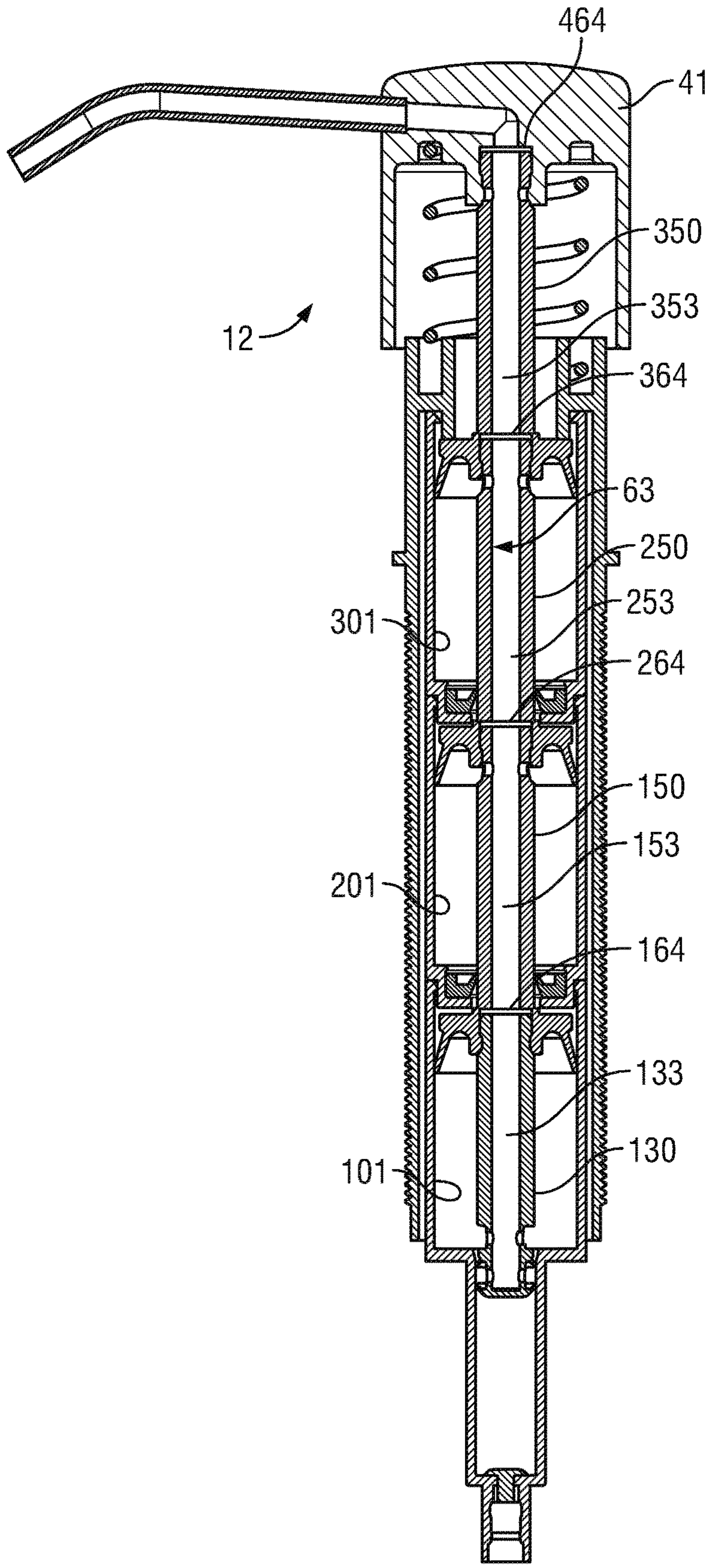
FIG. 14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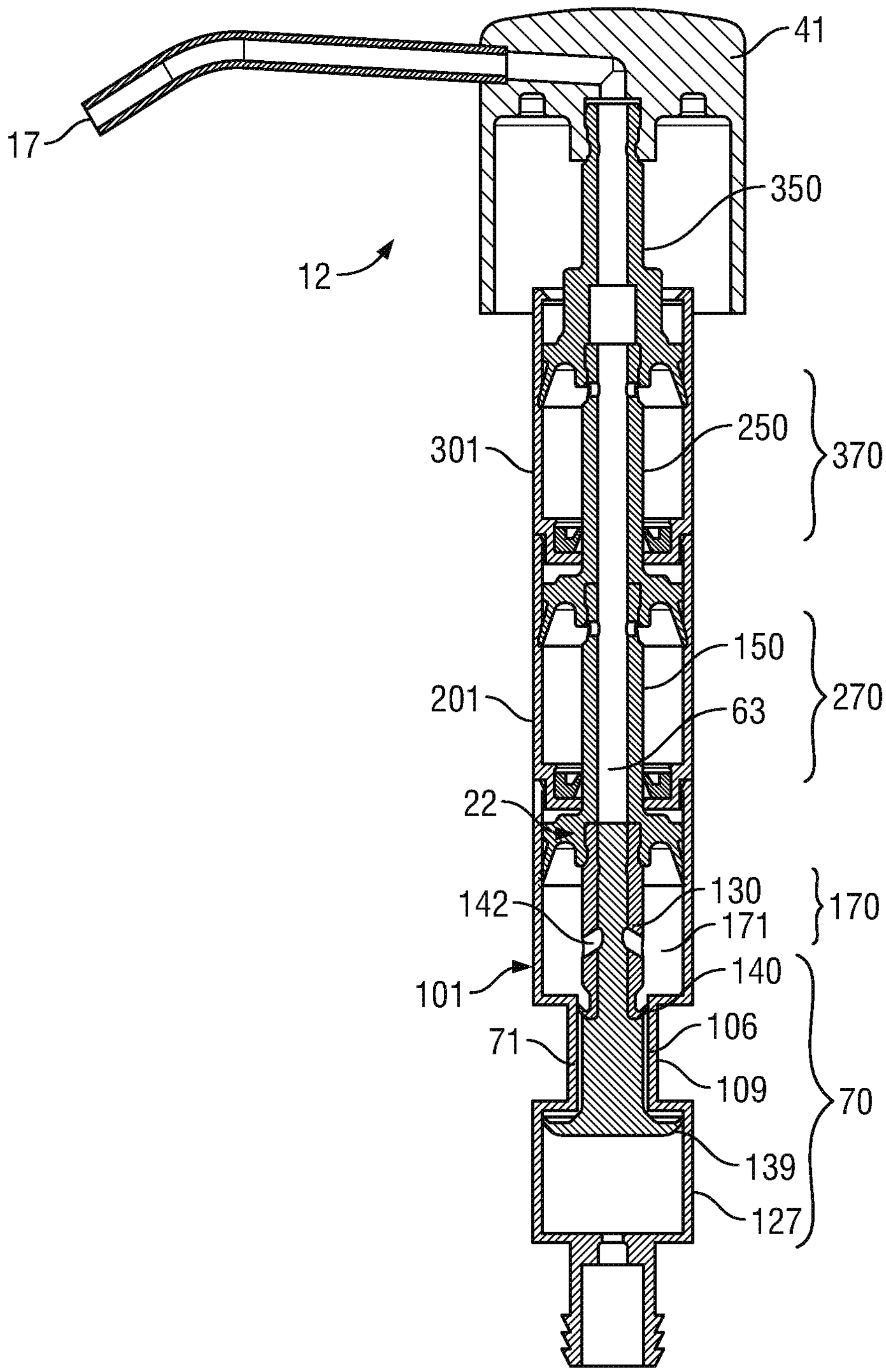
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FIG. 16

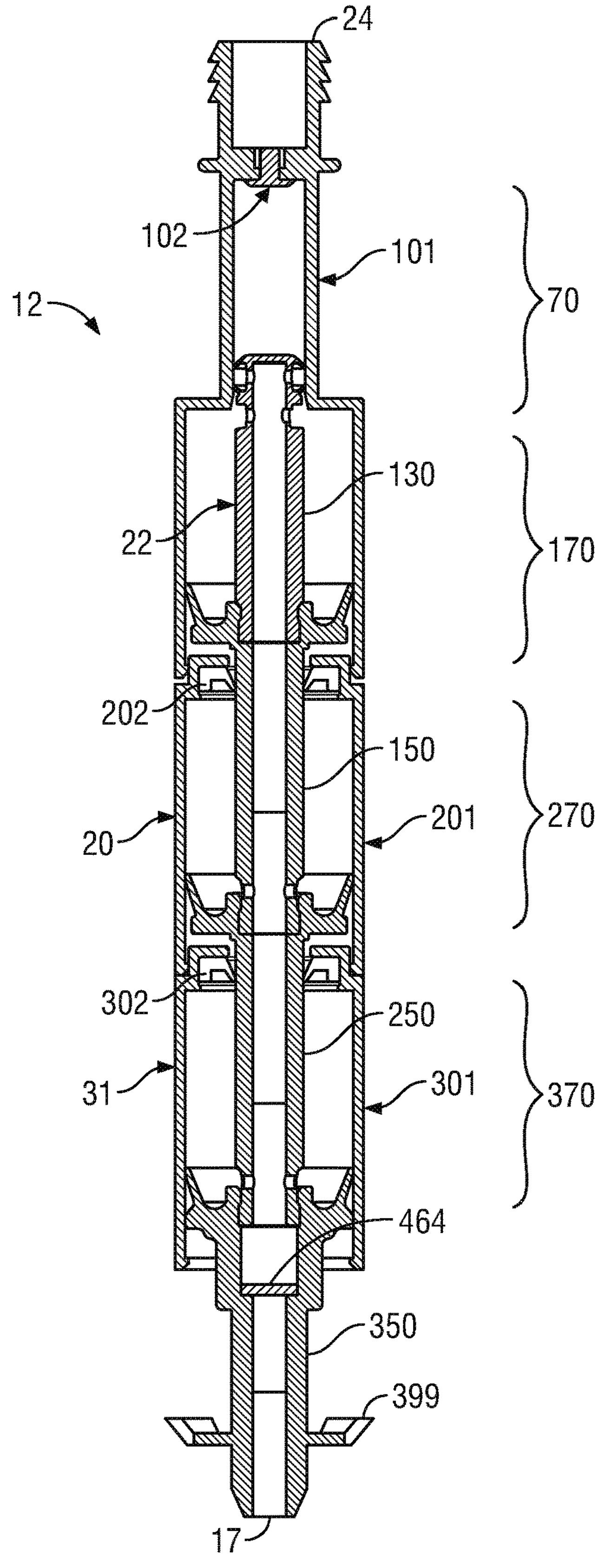
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FIG. 17

MULTIPLE AIR CHAMBER FOAM PUMP

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

SCOPE OF THE INVENTION

This invention relates to foam pumps for dispensing liquid mixed with air as a foam and, more particularly, to a piston pump with multiple axially spaced air pumps.

BACKGROUND OF THE INVENTION

Liquid piston pumps for dispensing liquid through a countertop from a reservoir disposed below the countertop are known in which the body of the pump is inserted through an opening in the countertop into a reservoir, with merely an actuator and discharge outlet above the countertop. These liquid pumps are operative in a single stroke as to allow the production of a desired unit dosage volume of liquid. The opening through the countertop is selected to be as small as possible, for example, ⅞ inch in diameter, to provide a pleasing appearance.

Foam piston pumps are known for simultaneously dispensing a liquid mixed with air as in a foam. One such foaming pump is disclosed, for example, in U.S. Pat. No. 7,337,930 to Ophardt et al, issued Mar. 4, 2008, the disclosure of which is incorporated herein by reference.

The inventor of the present application has appreciated that previously known foam piston pumps suffer the disadvantage that the pumps typically cannot be inserted through a relatively small opening into a reservoir and have a reasonable stroke length while allowing an adequate volume of air to be displaced as to allow the production of a desired unit dosage volume of foamed liquid product in a single stroke. The present inventor has also appreciated the disadvantage that with known foam piston pumps, as the diameter of the opening through which the pump is to be inserted reduces, then the stroke length required to dispense a desired volume of air increases.

SUMMARY OF THE INVENTION

To at least partially overcome these disadvantages of previously known devices, the present invention provides an improved foam piston pump in which a multiple of air pumps are disposed coaxially about a piston member and spaced axially along the piston member.

In one aspect, the present invention provides a piston pump comprising:

a piston chamber-forming member extending longitudinally about an axis from a lower end to an upper end;

the piston chamber-forming member defining a central chamber therein coaxially about the axis within an annular chamber wall;

the piston chamber-forming member having a liquid inlet at the lower end in communication with a liquid in a reservoir;

a piston-forming element coaxially slidably received within the chamber in the piston chamber-forming member;

the piston-forming element comprising an elongate tubular stem with a central passageway longitudinally therethrough, the passageway extending from a lower end to an upper end;

the piston-forming element coaxially slidable within the piston chamber-forming member between an extended position and a retracted position in a cycle of operation comprising a withdrawal stroke and a retraction stroke to draw the liquid from the reservoir via the liquid inlet and discharge the liquid mixed with air through the upper end of the passageway;

a liquid pump formed between the piston chamber-forming member and the piston-forming element proximate the lower end of the piston chamber-forming member, the liquid pump operative in the cycle of operation to draw the liquid from the reservoir via the liquid inlet and discharge the liquid into the passageway proximate the lower end of the passageway;

a lower air pump formed between the piston chamber-forming member and the piston-forming element above the liquid pump operative in the cycle of operation in a withdrawal stroke to draw air from the atmosphere and in a retraction stroke to discharge air into the passageway through a lower air port which extends radially inwardly through the stem into the passageway;

a first upper air pump formed between the piston chamber-forming member and the piston-forming element axially above the lower air pump, the first upper air pump operative in the cycle of operation in the withdrawal stroke to draw air from the atmosphere and in the retraction stroke to discharge air into the passageway through a first upper air port which extends radially inwardly through the stem into the passageway at an axial location on the stem spaced axially above the lower air port;

a first upper air sealing annular flange on the piston chamber-forming member above the lower air pump, the first upper air sealing annular flange extending from the chamber wall radially inwardly to an annular distal edge in engagement with a radially outwardly directed first upper cylindrical wall on the stem axially above the first upper air port;

the annular distal edge of the first upper air sealing annular flange engaging the first upper cylindrical wall of the stem to prevent fluid flow axially inwardly therepast,

a first upper air sealing disc on the stem axially above the first upper air sealing annular flange on the piston chamber-forming member;

the first upper air sealing disc extending radially outwardly from the stem to an annular distal edge in engagement with a first cylindrical upper portion of the chamber wall on the piston chamber-forming member axially above the first upper air sealing annular flange;

the annular distal edge of the first upper air sealing disc engaging the first cylindrical upper portion of the chamber wall on the piston chamber-forming member to prevent fluid flow axially upwardly therepast;

the first upper air pump having a first upper air compartment open to the first upper air port and defined (a) annularly between the stem of the piston-forming element and the first cylindrical upper portion of the chamber wall of the piston chamber-forming member, and (b) axially between the first upper air sealing annular flange and the first upper air sealing disc;

in a cycle of operation in the withdrawal stroke, an axial distance between the first upper air sealing annular flange and the first upper air sealing disc increases thereby increasing a volume of the first upper air compartment and drawing air into the first upper air compartment and, in the retraction stroke, the axial distance between the first upper air sealing annular flange and the first upper air sealing disc decreases thereby decreasing the volume of the first upper air compartment and discharging air from the first upper air compartment through the first upper air port into the passageway.

In another aspect, the present invention provides a piston pump comprising:

a piston chamber-forming member extending longitudinally about an axis from an inner end to an outer end;

the piston chamber-forming member defining a central chamber therein coaxially about the axis within an annular chamber wall;

the piston chamber-forming member having a liquid inlet at the inner end in communication with a liquid in a reservoir;

a piston-forming element coaxially slidably received within the chamber in the piston chamber-forming member;

the piston-forming element comprising an elongate tubular stem with a central passageway longitudinally therethrough, the passageway extending from an inner end to an outer end;

the piston-forming element coaxially slidable within the piston chamber-forming member between an extended position and a retracted position in a cycle of operation comprising a withdrawal stroke and a retraction stroke to draw the liquid from the reservoir via the liquid inlet and discharge the liquid mixed with air through the outer end of the passageway;

a liquid pump formed between the piston chamber-forming member and the piston-forming element proximate the inner end of the piston chamber-forming member, the liquid pump operative in the cycle of operation to draw the liquid from the reservoir via the liquid inlet and discharge the liquid into the passageway proximate the inner end of the passageway;

an inner air pump formed between the piston chamber-forming member and the piston-forming element axially outwardly of the liquid pump operative in the cycle of operation in a withdrawal stroke to draw air from the atmosphere and in a retraction stroke to discharge air into the passageway through an inner air port which extends radially inwardly through the stem into the passageway;

a first outer air pump formed between the piston chamber-forming member and the piston-forming element axially outwardly of the inner air pump, the first outer air pump operative in the cycle of operation in the withdrawal stroke to draw air from the atmosphere and in the retraction stroke to discharge air into the passageway through a first outer air port which extends radially inwardly through the stem into the passageway at an axial location on the stem spaced axially outwardly of the inner air port;

a first outer air sealing annular flange on the piston chamber-forming member axially outwardly of the inner air pump, the first outer air sealing annular flange extending from the chamber wall radially inwardly to an annular distal edge in engagement with a radially outwardly directed first outer cylindrical wall on the stem axially inwardly of the first outer air port;

the annular distal edge of the first outer air sealing annular flange engaging the first outer cylindrical wall of the stem to prevent fluid flow axially inwardly therepast,

a first outer air sealing disc on the stem axially outwardly of the first outer air port and axially outwardly of the first outer air sealing annular flange on the piston chamber-forming member;

the first outer air sealing disc extending radially outwardly from the stem to an annular distal edge in engagement with a first cylindrical outer portion of the chamber wall on the piston chamber-forming member axially outwardly of the first outer air sealing annular flange;

the annular distal edge of the first outer air sealing disc engaging the first cylindrical outer portion of the chamber wall on the piston chamber-forming member to prevent fluid flow axially upwardly therepast;

the first outer air pump having a first outer air compartment open to the first outer air port and defined (a) annularly between the stem of the piston-forming element and the first cylindrical outer portion of the chamber wall of the piston chamber-forming member, and (b) axially between the first outer air sealing annular flange and the first outer air sealing disc;

in a cycle of operation in the withdrawal stroke, an axial distance between the first outer air sealing annular flange and the first outer air sealing disc increases thereby increasing a volume of the first outer air compartment and drawing air into the first outer air compartment and, in the retraction stroke, the axial distance between the first outer air sealing annular flange and the first outer air sealing disc decreases thereby decreasing the volume of the first outer air compartment and discharging air from the first outer air compartment through the first outer air port into the passageway.

BRIEF DESCRIPTION OF THE DRAWINGS

Further aspects and advantages of the present invention will become apparent from the following description taken together with the accompanying drawings in which:

FIG. **1** is cross-sectional front view of a dispenser with a foam pump in accordance with the first embodiment of the present invention in an extended position;

FIG. **2** is an enlarged side view of the pump of FIG. **1** in the extended position;

FIG. **3** is a side view the same as FIG. **2** but showing the pump in a retracted condition;

FIG. **4** is a cross-sectional side view of a piston chamber-forming member of the pump in FIG. **2**;

FIG. **5** is an exploded cross-sectional side view of the piston chamber-forming member of FIG. **4**;

FIG. **6** is an exploded pictorial cross-sectional view of the piston chamber-forming member of FIG. **4**;

FIG. **7** is a cross-sectional side view of a piston-forming element and a spring of the pump of FIG. **2**;

FIG. **8** is an exploded cross-sectional side view of the piston-forming element and the spring of FIG. **7**;

FIG. **9** is an exploded pictorial cross-sectional view of the piston-forming element and the spring of FIG. **7**;

FIG. **10** is an enlarged pictorial view of the liquid piston of the piston-forming element shown in FIG. **8**;

FIG. **11** is an enlarged pictorial view of one of the air piston portions of the piston-forming element shown in FIG. **8**;

FIG. 12 is a side view of a foam pump in accordance with a second embodiment of the present invention in an extended position;

FIG. 13 is a side view of a foam pump in accordance with a third embodiment of the present invention in an extended position;

FIG. 14 is a side view of a foam pump in accordance with a fourth embodiment of the present invention in an extended position;

FIG. 15 is a side view of a foam pump in accordance with a fifth embodiment of the present invention in an extended position;

FIG. 16 is a side view of a foam pump in accordance with a sixth embodiment of the present invention in an extended position; and

FIG. 17 is a side view of a foam pump in accordance with a seventh embodiment of the present invention in an extended position.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is made to FIG. **1** which illustrates a dispenser **10** incorporating a pump **12** in accordance with the first embodiment of the present invention. The dispenser **10** includes a reservoir **13** containing a fluid **14**. The reservoir **13** has a cylindrical upwardly opening neck **15** and the pump **12** extends downwardly through the neck **15** into the reservoir **13** and is operative to dispense fluid **14** from the reservoir out a discharge outlet **17** on the pump **12**. As shown in FIG. **1**, the reservoir **13** is fixedly secured to a countertop **16** with the neck **15** extending upwardly through an opening **18** through the countertop **16** and being engaged by a threaded collar **19** to secure the reservoir **13** to the countertop **16** underneath the countertop **16**. The pump **12** is vertically slidable within the neck **15** for removal and replacement. With the pump **12** removed, the reservoir **13** may be replenished with the fluid **14** by a user pouring fluid downwardly into the reservoir **13** through the neck **15**. This arrangement is useful, for example, in a kitchen or washroom, to provide for dispensing of foamed cleaning fluid by use of the pump **12** above the top of countertop **16** from the reservoir **13** permanently secured below the countertop **16**, yet with substantial portions of the pump **12** disposed below the countertop **16**.

The pump **12** comprises a piston chamber-forming member **20**, a spring **21** and a piston-forming element **22**.

As seen in FIG. **4**, the piston chamber-forming member **20** extends longitudinally about a central axis **23** from a lower end **24** to an upper end **25**. The piston chamber-forming member **20** defines a central chamber **26** therein coaxially about the axis **23** and within an annular chamber wall **27**. The piston chamber-forming member **20** has a liquid inlet **28** at the lower end **24** in communication with the liquid **14** in the reservoir **13**. As seen only in FIG. **1**, a hollow dip tube **29** is coupled to the lower end **24** of the piston chamber-forming member **20** by which the liquid inlet **28** is in communication with fluid **14** in the reservoir **13**.

Reference is made to FIGS. **5** and **6** which show in exploded views components of the piston chamber-forming member **20**. These components comprise:

- a housing **31**;
- a lower casing assembly **100** including a lower casing **101** and a one-way valve **102**;
- a first upper casing assembly **200** comprising a first upper casing **201** and a first upper annular seal disc **203**; and
- a second upper casing assembly **300** comprising a second upper casing **301** and a second upper annular seal disc **303**.

In the preferred embodiment, the first upper casing assembly **200** is identical to the second upper casing assembly **300** and each may be considered to be an identical modular component, which is advantageous but not necessary as each may be different.

The lower casing **101** extends from the lower end **24** to an upper end **105** and defines therein a liquid chamber **106** and coaxially above the liquid chamber **106** a lower air chamber **107**. The lower casing **101** has a wall **108** with a cylindrical first lower portion **109** and a cylindrical second lower portion **110**. The liquid chamber **106** is defined within the cylindrical first lower portion **109** of the wall **108**. The lower air chamber **107** is defined within the cylindrical second lower portion **110** of the wall **108**. The liquid chamber **106** has a diameter which is less than the diameter of the lower air chamber **107**. The wall **108** includes a radially inwardly extending shoulder **111** which forms a lower end **112** of the lower air chamber **107**. The liquid chamber **106** opens at an upper end **113** through the shoulder **111** coaxially into the lower air chamber **107**. The wall **108** extends inwardly as a shoulder **114** at a lower end **115** of the liquid chamber **106**. An opening **116** through the shoulder **114** at the lower end **115** of the liquid chamber **106** opens via a passageway **117** to the lower end **24**.

The one-way valve **102** is secured in a friction-fit relation within the opening **116** at the lower end **115** of the liquid chamber **106**. The one-way valve **102** has a fluted stem **118** and a resilient annular disc **119** extending radially outwardly from the stem **118** at the upper end of the one-way valve **102**. The stem **118** carries axially extended flutes permitting fluid flow axially past the stem **118** when the one-way valve **102** is snap-fitted within the opening **116**. The disc **119** is resilient and biased such that under its inherent bias a circumferential edge of the disc **119** engages the shoulder **114** to prevent fluid flow downwardly from the liquid chamber **106** to the reservoir **13**. The disc **119** is deflectable such that when the pressure in the liquid chamber **106** is less than the pressure in the reservoir **13** fluid will flow upwardly past the disc **119** from the reservoir **13** into the liquid chamber **106**. The wall **108** of the lower casing **101** at its upper end **105** defines an inwardly directed annular catch shoulder **125** with an annular surface directed at least in part axially downwardly.

The first upper casing **201** has a lower end **204** and an upper end **205**. The first upper casing **201** has a wall **208** with a cylindrical upper portion **210** defining a first upper air chamber **207** therein. The wall **208** includes a radially inwardly extending annular upper shoulder **211** which forms a lower end **212** of the first upper air chamber **207**. An opening **216** extends through the upper shoulder **211**. The wall **208** also includes a radially inwardly extending annular lower shoulder **220**. An opening **221** extends through the lower shoulder **220**. The wall **208** defines between the upper shoulder **211** and the lower shoulder **220** an annular recess **223**. The opening **216** through the upper shoulder **111** has a diameter less than a diameter of the recess **223** and less than a diameter of the opening **221** through the lower shoulder **220** such that the seal disc **203** which is resilient may be forced downwardly into the recess **223** past the shoulder **214** to be received within the recess **223** against removal.

The first upper casing **201** has an opening **224** at its upper end **205**. The wall **208** of the first upper casing **201** at its upper end **205** defines an inwardly directed annular catch shoulder **225** with an annular surface directed at least in part axially downwardly.

The wall **208** of the first upper casing **201** carries about its lower end **204** a radially outwardly extending catching shoulder **226** with an annular surface directed at least in part axially upwardly. The upper end **105** of the lower casing **101** is adapted to engage the lower end **204** of the first upper casing **201** in a snap-fit relation with the catch shoulder **125** of the lower casing **101** to engage the catching shoulder **226** of the first upper casing **201** to resist disengagement.

The second upper casing **301** has a wall **308** with a cylindrical upper portion **310** defining a second upper air chamber **307** therein. The wall **308** includes a radially inwardly extending annular upper shoulder **311** which forms a lower end **312** of the second upper air chamber **307**. An opening **316** extends through the upper shoulder **311**. The wall **308** also includes a radially inwardly extending annular lower shoulder **320**. An opening **321** extends through the lower shoulder **320**. The wall **308** defines between the upper shoulder **311** and the lower shoulder **320** an annular recess **323**. The opening **316** through the upper shoulder **311** has a diameter less than the diameter of the recess **323** and less than a diameter of the opening **321** through the lower shoulder **320** such that the seal disc **303** which is resilient may be forced downwardly into the recess **323** past the shoulder **314** to be received within the recess **323** against removal. The wall **308** of the second upper casing **301** at its upper end **305** defines an inwardly directed annular catch shoulder **325** with an annular surface directed at least in part axially downwardly.

The wall **308** of the second upper casing **301** carries about the opening **324** at its lower end **304** a radially outwardly extending catching shoulder **326** with an annular surface directed at least in part axially upwardly. The upper end **205** of the upper air casing **201** is adapted to engage the lower end **304** of the second upper casing **301** in a snap-fit relation with the catch shoulder **225** of the first upper casing **201** to engage the catching shoulder **326** of the second upper casing **301** to resist disengagement.

The housing **31** comprises a generally cylindrical outer tube **401** extending coaxially about the axis **23**. The outer tube **401** has a lower end **404** and an upper end **405**. Proximate the upper end **405** of the outer tube **401**, an annular flange **406** extends radially inwardly from the outer tube **401**. The annular flange **406** the supports a cylindrical inner tube **407** which extends coaxial with the outer tube **401** about the axis **23**. The inner tube **407** has a lower end **408** and an upper end **409**. The lower end **408** of the inner tube **407** carries a radially outwardly extending catching shoulder **426** with an annular surface directed at least in part axially upwardly.

The upper end **305** of the second upper air casing **301** is adapted to engage the lower end **408** of the inner tube **407** in a snap-fit relation with the catch shoulder **325** of the second upper casing **301** to engage the catching shoulder **426** of the inner tube **407** of the housing to resist disengagement.

The first annular seal disc **203** comprises a radially outermost annular ring **230** from which an annular sealing flange **231** extends radially inwardly to an annular distal end **232**. The annular sealing flange **231** extends from the ring **230** radially inwardly and axially upwardly to the distal end **232**.

The second annular seal disc **303** comprises a radially outermost annular ring **330** from which an annular sealing flange **331** extends radially inwardly to an annular distal end **332**. The annular sealing flange **331** extends from the ring **330** radially inwardly and axially upwardly to the distal end **332**.

In an assembled piston chamber-forming member **20** as seen in FIG. **4**, the lower casing **101** is secured in a friction-fit relation to the first upper casing **201** which is secured in a friction-fit relation to the second upper casing **301** which is secured in a friction-fit relation to the housing **31**. The one-way valve **102** is secured in a friction-fit relation to the lower casing **101**. The first annular seal disc **203** is snap-fitted into the recess **223** of the first upper casing **201**. The second annular seal disc **303** is secured in a friction-fit relation into the recess **323** of the second upper casing **301**. The annular chamber wall **27** includes the wall **108**, the wall **208** and the wall **308**. The central chamber **26** includes, axially inline one above the other, the liquid chamber **106**, the lower air chamber **107**, the first upper air chamber **207** and the second upper air chamber **307** in axial communication with each other via the openings **113**, **221**, **216**, **321** and **316**.

Reference is made to FIGS. **7** to **11** which illustrate the piston-forming element **22**. As best seen in the exploded views of FIGS. **8** and **9**, the piston-forming element **22** includes a liquid piston **130**, a lower air piston **150**, a first upper air piston **250**, a second upper air piston **350**, a foam producing member **464**, a head **41** and an outlet tube **40**. In the first embodiment shown, each of the lower air piston **150** and the first upper air piston **250** is identical and each may be considered to be an identical modular component, which is advantageous but not necessary as each may be different. The second upper air piston **350** is identical to the lower air piston **150** with the exception that there is no equivalent on the second upper air piston **350** to the air port **162**. The second air piston **350** may be identical to the lower air piston **150** with the second air piston **350** having an air port, not shown, identical to the air port **162** provided that the head **41** engages the second air piston **350** in a manner to sealably close the air port on the second air piston **350**.

The lower air piston **150** has an elongate tubular stem **151** with a tubular wall **152**. The stem **151** of the lower air piston **150** has a lower end **154** and an upper end **155**. The tubular wall **152** defines a central passageway **153** longitudinally therethrough from the lower end **154** to the upper end **155** open at each end. The lower air piston **150** carries a first lower air sealing disc **156** which extends radially outwardly and axially downwardly from the stem **151** to an annular distal edge **157**. Proximate the upper end **155**, a radially outwardly directed surface **158** of the wall **152** of the stem **151** carries a radially outwardly extending catching shoulder **159** with an annular surface directed, at least in part, axially downwardly. Proximate the lower end **154**, the stem **151** carries a socket **160** with a radially inwardly extending catch shoulder **161** with an annular surface directed, at least in part, axially upwardly. A first upper air port **162** is provided on the stem **151** and extends radially through the wall **152** of the stem **151** into the passageway **153**. The first upper air port **162** is on the stem **151** above the lower air sealing disc **156**. In FIG. **8** as shown, two such first upper air ports **162** are provided at diametrically opposed positions on the stem **151**, however, only one is necessary. The radially outwardly directed surface **158** of the wall **152** of the stem **151** is cylindrical over a cylindrical portion **163** between the first lower air sealing disc **156** and the upper end **155**.

The first upper air piston **250** has an elongate tubular stem **251** with a tubular wall **252**. The stem **251** of the first upper air piston **250** has a lower end **254** and an upper end **255**. The tubular wall **252** defines a central passageway **253** longitudinally therethrough from the lower end **254** to the upper end **255** open at each end. The first upper air piston **250** carries a first upper air sealing disc **256** which extends radially outwardly and axially downwardly from the stem **251** to an annular distal edge **257**. Proximate the upper end **255**, a radially outwardly directed surface **258** of the wall **252** of the stem **251** carries a radially outwardly extending catching shoulder **259** with an annular surface directed at least in part axially downwardly. Proximate the lower end **254**, the stem **251** carries a socket **260** with radially inwardly extending catch shoulder **261** with an annular surface directed at least in part axially upwardly. A second upper air port **262** is provided on the stem **251** and extends radially through the wall **252** of the stem **251** into the passageway **253**. The second upper air port **262** is on the stem **251** above the first upper air sealing disc **256**. The radially outwardly directed surface **258** of the wall **252** of the stem **251** is cylindrical over a cylindrical portion **263** between the first upper air sealing disc **256** and the upper end **255**.

The second upper air piston **350** has an elongate tubular stem **351** with a tubular wall **352**. The stem **351** of the second upper air piston **350** has a lower end **354** and an upper end **355**. The tubular wall **352** defines a central passageway **353** longitudinally therethrough from the lower end **354** to the upper end **355** open at each end. The second upper air piston **350** carries a second upper air sealing disc **356** which extends radially outwardly and axially downwardly from the stem **351** to an annular distal edge **357**. Proximate the upper end **355**, a radially outwardly directed surface **358** of the wall **352** of the stem **351** carries a radially outwardly extending catching shoulder **359** with an annular surface directed at least in part axially downwardly. Proximate the lower end **354**, the stem **351** carries a socket **360** with radially inwardly extending catch shoulder **361** with an annular surface directed at least in part axially upwardly. The radially outwardly directed surface **358** of the wall **352** of the stem **351** is cylindrical over a cylindrical portion **363** between the second upper air sealing disc **356** and the upper end **355**.

The upper end **155** of the lower air piston **150** is adapted to be secured in a snap-fit relation against removal in the socket **260** of the first upper air piston **250** to secure the lower air piston **150** to the first upper air piston **250** with the catching shoulder **159** of the lower air piston **150** in opposition to the catch shoulder **261** of the socket **260** of the first upper air piston **250**. Similarly, the upper end **255** of the first upper air piston **250** is adapted to be secured in a snap-fit relation against removal in the socket **360** of the second upper air piston **350** to secure the first upper air piston **250** to the second upper air piston **350** with the catching surface **259** of the first upper air piston **250** in opposition to the catch shoulder **361** of the socket **360** of the second upper air piston **350**.

The liquid piston **130** has an elongate tubular stem **131** with a tubular wall **132**. The stem **131** of the liquid piston **130** has a lower end **134** and an upper end **135**. The tubular wall **132** defines a central passageway **133** longitudinally therethrough from the lower end **134** to the upper end **135**. The passageway **133** is open at the upper end **135**. The passageway **133** is closed at the lower end **134** by an end wall **136**.

Proximate the upper end **135**, a radially outwardly directed surface **137** of the wall **132** of the stem **131** carries a radially outwardly extending catching shoulder **138** with an annular surface directed, at least in part, axially downwardly. The upper end **135** of the liquid piston **130** is adapted to be secured in a snap-fit relation against removal in the socket **160** of the lower air piston **150** to secure the liquid piston **130** to the lower air piston **150** with the catching shoulder **138** of the liquid piston **130** in opposition to the catch shoulder **161** of the socket **160** of the lower air piston **150**.

The liquid piston **130** carries proximate its lower end **134**, a radially outwardly extending liquid sealing disc **139**. The lower liquid piston **130** carries proximate its lower end **134**, a radially outwardly extending second lower air sealing disc **140** spaced axially upwardly from the liquid sealing disc **139**. A liquid port **141** is provided on the stem **131** axially between the liquid sealing disc **139** and the second lower air sealing disc **140**. The liquid port **141** extends radially through the wall **132** of the stem **131** into the passageway **131**. A lower air port **142** is provided on the stem **131** above the lower air disc **142**. The lower air port **142** extends radially through the wall **132** of the stem **131** into the passageway **131**.

Over a cylindrical portion **143** between lower air port **142** and the upper end **135**, the radially outwardly directed surface **137** of the wall **132** of the stem **131** is cylindrical.

The head **41** comprises a top portion **42** from which an outer tube **43** extends about the axis **23** downwardly to an open lower end **44**. The top portion **42** has an upper surface **46** and a lower surface **47**. An inner tube **48** extends downwardly from the lower surface **47** coaxially about the axis **23** to an open lower end **62**. Within the inner tube **48**, a socket **49** is provided having a catch shoulder **50** with an annular surface directed, at least in part, axially upwardly. A discharge passageway **51** is provided within the head **41** between an opening **52** coaxially within the socket **49** at an upper end of the socket **49** to an opening **53** directed forwardly. The outlet tube **40** is a hollow tube with a tube passageway **54** therethrough from a first end **55** to a second forward end **56** providing the discharge outlet **17**. The outlet tube **40** is coupled to the top portion **42** with the first end **55** secured within the opening **53**.

On the head **41**, a downwardly opening annular groove **57** is provided in the lower surface **47** coaxially between the outer tube **43** and the inner tube **48** with a blind upper end **58** to receive an upper end **59** of the spring **21**. On the housing **31**, an upwardly opening annular groove **60** is provided coaxially between the outer tube **401** and the inner tube **407** with a blind upper end **61** on the annular flange **406** to receive a lower end **62** of the spring **21**. In the assembled piston-forming element as seen in FIG. **7**, a passageway **63** extends therethrough from the lower end **135** to the discharge outlet **17** including the central passageways **133**, **153**, **253** and **353**, the socket **49**, the discharge passageway **51** and the tube passageway **54**.

The assembled piston-forming element **22** has an elongate tubular stem **90** formed by the stems **131**, **151**, **251** and **351** with the central passageway **63** longitudinally therethrough including the passageways **133**, **153**, **253** and **353**. The passageway **63** extends from a lower end **134** of the passageway **133** to an upper end **355** of the passageway **353**.

The upper end **355** of the second upper air piston **350** is adapted to be secured in a snap-fit relation against removal in the socket **49** of the head **41** to secure the second upper air piston **350** to the head **41** with the catching surface **359** of the second upper air piston **350** in opposition to the catch shoulder **50** of the socket **49** of the head **41**. The foam producing member **464** is located within the socket **49** and sandwiched between the upper end of the socket **49** and the upper end **355** of the upper air piston **350** axially upwardly of the upper end **355**.

Air and liquid passing outwardly through the passageway **63** passes through the foam producing member **464** to create a foam of air and liquid as, for example, by creating turbulence in the fluids as they pass through the foam producing member **464**. The foam producing member **464** may preferably comprise a screen member with suitably sized openings.

Reference is made to FIGS. **1** and **2** which show the assembled pump **12** in an extended position with the piston-forming element **22** engaged with the piston chamber-forming member **20**. The spring **21** is in its inherent unbiased position. In use, from the position of FIGS. **1** and **2**, a user manually applies downwardly directed forces to the upper surface **46** of the top portion **42** of the head **41** to axially compress the spring **21** against its inherent bias and move the piston-forming element **22** coaxially downwardly along the central axis **23** relative to the piston chamber-forming member **20** to the retracted position as shown in FIG. **3**. The spring **21** has an inherent bias and from the retracted position of FIG. **3** on release of the manual pressure, the spring **21** will move the piston-forming element **22** upwardly from the retracted position of FIG. **3** to the extended position of FIG. **2**. As seen in FIG. **5**, the outer tube **401** of the piston chamber-forming member has a radially outwardly extending annular flange **427** which, as seen in FIG. **1**, engages the uppermost end of the neck **15** of the reservoir **13** to prevent downward movement of the piston chamber-forming member **20** relative to the countertop **16** and the reservoir **13**. A cycle of operation arises in the relevant movement of the piston-forming element **22** from the extended position of FIG. **2** to the retracted position of FIG. **3** in a retraction stroke and then from the retracted position of FIG. **3** to the extended position of FIG. **2** in a withdrawal or extension stroke. In the assembled pump **10**, as seen in FIGS. **2** and **3**, the cylindrical portion **263** of the stem **251** of the first upper air piston **250** passes through the second annular seal disc **303** with the annular distal end **332** of the annular sealing flange **331** engaging the cylindrical portion **263** of the stem **251** to form a seal therewith preventing fluid flow therepast axially downwardly.

The second upper air sealing disc **356** of the second upper air piston **350** engages the radially inwardly directed cylindrical surface of the cylindrical upper portion **310** of the second upper casing **301** forming a seal therewith to prevent fluid flow axially upwardly therepast. A second upper air pump **370** is thereby formed within the second upper casing **301** between the second upper casing assembly **300** and the piston forming element **22**. The second upper air pump **370** provides a cylindrical second upper air compartment **371** radially in between the cylindrical upper portion **310** of the wall **308** of the second upper casing **301** and the stem **251** of the first upper air piston **250** and axially between the first upper air sealing disc **356** and the second annular seal disc **303**. The second upper air port **262** provides communication between the second upper air compartment **371** and the passageway **253**.

The volume of the second upper air compartment **371** varies with relative movement of the piston-forming element **22** relative to the piston chamber-forming member **20** with the volume being largest in the extended position of FIG. **2** and smallest in the retracted position of FIG. **3**. In a retraction stroke in moving from the extended position of FIG. **2** to the retracted position of FIG. **3** the volume of the second upper air compartment **371** decreases and fluid therein, typically substantially air, is compressed and forced out of the second upper air port **262** into the passageway **253** and hence out the discharge outlet **17**. In a withdrawal stroke the volume of the second upper air compartment **371** increases and, fluid is drawn via the discharge outlet **17** into the passageway **253** and via the second upper air port **262** into the second upper air compartment **371**.

In the assembled pump **10**, as seen in FIGS. **2** and **3**, the cylindrical portion **163** of the stem **151** of the lower air piston **150** passes through the first annular seal disc **203** with the annular distal end **232** of the annular sealing flange **231** engaging the cylindrical portion **163** of the stem **151** to form a seal therewith preventing fluid flow therepast axially downwardly.

The first upper air sealing disc **256** of the first upper air piston **250** engages the radially inwardly directed cylindrical surface of the cylindrical upper portion **210** of the first upper casing **201** forming a seal therewith to prevent fluid flow axially upwardly therepast. A first upper air pump **270** is thereby formed within the first upper casing **201** between the first upper casing assembly **200** and the piston forming element **22**. The first upper air pump **270** provides a cylindrical first upper air compartment **271** radially in between the cylindrical upper portion **210** of the wall **208** of the first upper casing **201** and the stem **151** of the lower air piston **150** and axially between the upper air sealing disc **256** and the first annular seal disc **203**. The first upper air port **162** provides communication between the first upper air compartment **271** and the passageway **153**.

The volume of the first upper air compartment **271** varies with relative movement of the piston-forming element **22** relative to the piston chamber-forming member **20** with the volume being largest in the extended position of FIG. **2** and smallest in the extended position of FIG. **3**. In a retraction stroke in moving from the extended position of FIG. **2** to the retracted position of FIG. **3** the volume of the first upper air compartment **271** increases and, fluid therein, typically substantially air, is compressed and forced out of the first upper air port **162** into the passageway **153** and hence out the discharge outlet **17**. In a withdrawal stroke the volume of the second upper air compartment **271** increases and fluid is drawn via the discharge outlet **17** into the passageway **153** and via the first upper air port **162** into the first upper air compartment **271**.

The lower air sealing disc **156** of the lower air piston **150** extends radially outwardly to sealably engage with the radially inwardly directed surface of the wall **108** of the lower casing **101** in the cylindrical second lower portion **110** within the lower air chamber **107**. The second lower air sealing disc **140** extends radially outwardly to sealably engage the wall **108** of the lower casing **101** in the cylindrical first lower portion **109** within the liquid chamber **106**. A lower air pump **170** is defined within the lower casing **101** between the lower air piston **150** and the lower casing **101**. The lower air pump **170** has an annular lower air compartment **171** which extends radially between the wall **108** of the lower casing **101** and the stem **151** of the lower air piston **150** and axially between the first lower air sealing disc **156** and the second lower air sealing disc **140**. The lower air port **142** provides communication between the lower air compartment **171** and the central passageway **133**. The lower air compartment **171** has a volume which varies as the piston-forming element **22** moved axially relative to the piston chamber-forming member **20**. The lower air compartment **171** has a largest volume in the extended position of FIG. **2** and a smallest volume in the retracted position of FIG. **3** with this volume decreasing with movement of the piston-forming element **22** axially downwardly since the lower air compartment **171** is formed within a stepped chamber formed by the lower air chamber **107** and the lesser diameter liquid chamber **106**.

The liquid sealing disc **139** extends radially outwardly from the liquid piston **130** into engagement with the wall **108** of the lower casing **101** within the cylindrical first lower portion **109** of the liquid chamber **106**. The liquid sealing disc **139** extends radially outwardly to a distal end **145**. The liquid sealing disc **139** extends axially inwardly as it extends radially outwardly to the distal end **145** as seen in FIG. **10**. The liquid sealing disc **139** is resilient adopting an unbiased inherent condition as seen in FIG. **10** which preferably biases the distal end **143** of the liquid sealing disc **139** into the wall **108** of the cylindrical first lower portion **109** of the liquid chamber **106**. The liquid sealing disc **139** can be deflected against this bias away from the wall **108** to permit fluid flow upwardly therepast. As seen in FIG. **10**, the lower air sealing disc **140** extends radially outwardly to a distal end **144** which engages the wall **108** of the lower casing **101** in the cylindrical first lower portion **109** forming the liquid chamber **106** and substantially prevents liquid flow axially upwardly past the lower air sealing disc **140**. A liquid pump **70** is formed within the liquid chamber **106** between the stem **131** of the liquid piston **130** and the cylindrical first lower portion **109** of the lower casing **101** within the liquid chamber **106**. The liquid pump **70** has a liquid compartment **71** defined within the liquid chamber **106** between one-way valve **102** and the lower end **134** of the liquid piston **130**. The volume of the liquid compartment **71** varies with relative movement of the piston-forming element **22** within the piston chamber-forming member **20** with the volume being greatest in the extended position of FIG. **2** and least in the retracted position of FIG. **3**. On movement of the liquid piston **130** from the extended position of FIG. **2** to the retracted position of FIG. **3**, the volume of the liquid compartment **71** reduces compressing liquid within the liquid compartment **71** closing the one-way valve **102** to fluid flow downwardly from the liquid compartment **71** and with the pressure in the liquid compartment **71** deflecting the liquid sealing disc **139** for liquid flow upwardly past the liquid sealing disc **139** into an annular compartment between the annular sealing disc **139** and the second lower air sealing disc **140** and via the liquid port **141** into the central passageway **133** in a retraction stroke. In a withdrawal stroke, the volume of the liquid compartment **71** increases reducing the pressure within the liquid compartment **71** and drawing liquid from the reservoir past the one-way valve **102** into the liquid compartment **71**.

In the first embodiment illustrated in FIGS. **1** to **11**, each of the liquid pump **70**, the lower air pump **170**, the first upper air pump **270** and the second upper air pump **370** are all in phase such that they, in a retraction stroke, simultaneously discharge fluid from their respective compartments and, in a retraction stroke, simultaneously draw fluid into their respective compartments. Thus, for example, advantageously in a retraction stroke, a unit dosage of liquid is discharged into the passageway **63** by the liquid pump **70** and, simultaneously, a volume of air is discharged from each of the air pumps **170**, **270** and **370** so as to provide for the discharge of liquid and air simultaneously through the air forming member **464** forming foam which is discharged out the discharge outlet **17**.

In a withdrawal stroke, fluid, notably air, is withdrawn from the discharge outlet **17** through the passageway **63** and into each of the second upper air compartment **371**, the first upper air compartment **271** and lower air compartment **171** simultaneously with fluid being drawn into the liquid compartment **71** from the reservoir.

Reference is made to FIG. **12** which illustrates a second embodiment of a pump **10** in accordance with the present invention which is identical to the pump of the first embodiment, however, with the exception that the second upper air pump **370** has been eliminated by elimination from the pump **10** of the first embodiment as seen in FIG. **2** of the second upper casing assembly **300** and the first upper air piston **250**.

Reference is made to FIG. **13** which illustrates a third embodiment of a pump **10** in accordance with the present invention which is identical to the pump illustrated in FIG. **2**, however, in which a third upper air pump **570** is provided by providing a third upper casing assembly **500** with a third upper casing **501** and a third upper air piston **550** which are modular and substantially the same as, respectively, the second upper casing assembly **300** and the first upper air piston **250**.

A feature of the invention is that the pumps are configured to be made from modular components. The first upper casing assembly **200** and the second upper casing assembly **300** are identical in their casings **201** and **301** and in their first and second upper annular seal disc **203** and **303**. The lower air piston **150** and the first upper air piston **250** are identical. The second upper air piston **350** is identical to the lower air piston **150** with the exception that there is no equivalent on the second upper air piston **350** to the air port **162**. The second air piston **350** can be identical to the lower air piston **150** by firstly providing the second air piston **350** with an air port, not shown, identical to the air port **162** and, secondly, providing the head **41** to engage the second air piston **350** in a manner to sealably close the air port on the second air piston **350**, as can be accomplished by suitable modification of the socket **49** of the head **41**. The use of modular components for the casing assembly and piston for air pumps permits pump arrangements with one, two or three identical upper air pumps to be assembled from modular components as is apparent from a comparison of the embodiments of FIGS. **2**, **12** and **13**. Each of these embodiments provided have a constant diameter exterior about the upper air pumps.

Reference is made to FIG. **14** which illustrates a fourth embodiment of a piston pump **10** in accordance with the present invention which is identical to the piston pump as shown in FIG. **2** but for two exceptions. A first exception is that while in FIG. **2** the diameter of each of the central passageways **133**, **153**, **253** and **353** are identical and equal, in FIG. **14**, the diameter of the passageway **63** changes varies between the lower end **134** and the upper end of the central passageway **353** of the second upper air pump **350**, with the variation being an increase in diameter as the passageway **63** extends upwardly. The second exception is that in addition to the foam producing member **464** within the socket **49** of the head **41**, a foam producing member **364** is provided within the socket **360** of the second upper air piston **350**, a foam producing member **264** is provided within the socket **260** of the first upper air piston **250** and a foam producing member **164** is provided within the socket **160** of the lower air piston **150**. In operation of the pump of FIG. **14** in a retraction stroke, liquid from the liquid pump **70** and air from the first air pump **170** are passed through the foam producing member **164** to produce at least some foam as a first resultant product which is joined from air from the first upper air pump **270** and passed through the foam producing member **264** forming a second resultant foamed product which, together with air from the second upper air pump **370**, is passed first through the foam producing member **364** and then through the foam producing member **464** to produce a final resultant foam product which is delivered to the discharge outlet **17**. The arrangement of FIG. **14** with four foam producing members **164**, **264**, **364** and **464** provides for successive partial foaming of the air and fluid passing through each of the foam producing members. This is believed to be preferred for providing foam of desired characteristics. The increase in diameter and therefore the relative cross-sectional area of the passageway **66** axially upwardly can assist in adjusting the relative velocity of the fluid through the passageway **66** with a relative reduction in velocity compared to velocities which would arise in the arrangement in FIG. **2** as the fluid extends axially upwardly.

Reference is made to FIG. **15** which illustrates a fifth embodiment in accordance with the present invention which is identical to the embodiment of FIG. **14** with the exception that the diameter and therefore the cross-sectional area of the passageway **133** increases axially upwardly and above the passageway **133**, the passageway **63** decreases in diameter and, therefore, the cross-sectional area decreases axially upwardly successively through the central passageways **153**, **253** and **353**. In accordance with the present invention by a selection to use one or more of the foam producing members **164**, **264**, **354** and **464**, a selection of characteristics for each foam producing member used and a selection of the relative diameter for the passageway **63** and changes in the diameter along the length of the passageway **63**, advantageous configurations may be selected having regard to the relative velocity of fluid through the passageway at any location and the relative nature of the foam producing members. For example, it is believed to be desired that the relative opening size through the foam producing member is largest in the lower foam producing member **164** and the relative opening size is preferably to successively decrease to be smallest in the uppermost foam producing member **464**. While the embodiments of FIGS. **14** and **15** show four foam producing members **164**, **264**, **364** and **464**, it is to be understood that, alternatively, only one, two or three such foam producing members may be provided.

Reference is made to FIG. **16** which illustrates a sixth embodiment of a foam pump in accordance with the present invention. In FIG. **16**, the lower casing **101** has a liquid chamber **106** defined within a cylindrical second lower portion **109** and a cylindrical third lower portion **127** of a larger diameter than the cylindrical second lower portion **109**. The liquid sealing disc **139** is within the enlarged diameter second lower portion **109** while the lower air sealing disc **140** is within the lesser diameter cylindrical lower portion **109**. With movement of the piston-forming element **22** downwardly in a retraction stroke, the volume of the liquid compartment **71** between the second lower air sealing disc **140** and the liquid sealing disc **139** increases to draw liquid in from the reservoir and, in the withdrawal stroke, the volume in the liquid compartment **71** decreases deflecting the second lower air sealing disc **140** radially inwardly and axially upwardly such that liquid flows upwardly past the second lower air sealing disc **140** into the lower air compartment **171**. From the lower air compartment **171** via the lower air port **142**, liquid and air within the lower air compartment **171** are urged in a retraction stroke into the passageway **63** for discharge out the discharge outlet **17**. In the embodiment of FIG. **16**, the liquid pump **70** is out of phase with the air pumps **170**, **270** and **370** in the sense that in a retraction stroke, each of the air pumps is discharging fluid into the passageway **66** whereas the liquid pump **70** is drawing liquid into the liquid compartment **71** from the reservoir and, in a withdrawal stroke, the liquid pump **70** is discharging fluid into the lower air compartment **171** while each of the air pumps **170**, **270** and **370** is drawing air from the atmosphere into their respective air compartments **171**, **271** and **371**.

The particular nature of the liquid pump **70** for use in various embodiments is not limited and the liquid pump **70** may have valves as illustrated in the embodiment of FIG. **1** or a stepped chamber as illustrated in FIG. **16** and may be in phase or out of phase with each of the air pumps. Each of the air pumps is shown to be coaxially aligned and operate in phase simultaneously.

In the preferred embodiment, air which is drawn into each of the air pumps is atmospheric air drawn from the atmosphere via the discharge outlet **17**. This is not necessary. Various arrangements may be provided for atmospheric air to enter the air compartments in a retraction stroke without passing through the discharge outlet. For example, an arrangement for an air inlet valve could be provided as in the manner disclosed in U.S. Pat. No. 7,337,930 to Ophardt et al, issued Mar. 4, 2008.

The embodiments of FIGS. **1** to **16** illustrate arrangements which pump liquid upwardly from the reservoir **13**, that is, from the lower end **24** of the piston chamber-forming member **20** upwardly. Reference is made to FIG. **17** which illustrates a seventh embodiment in which the pump **12** pumps liquid downwardly. In FIG. **17**, similar reference numerals are used to identify equivalent elements in FIGS. **1** to **16**.

The seventh embodiment of FIG. **17** consists of an arrangement in which the pump **12** is the same as the pump **12** in the first embodiment of FIGS. **2** to **11**, but with the exceptions that pump **12** is inverted so that the end **24** of the piston chamber-forming member **20** is an upper end, both the head **41** and the tube **40** are eliminated, the air piston **350** is modified to provide the discharge outlet **17** at a lower end, and the air piston **350** is modified to carry an engagement flange **399** for engagement to slide the piston-forming element **22** relative the piston chamber-forming member **20**. With the end **24** in communication with liquid as in a liquid reservoir, such as an inverted bottle, not shown, liquid from the reservoir is dispensed downwardly by the liquid pump **70** simultaneously with the air pumps **170**, **270** and **370** discharging air to pass with the liquid downwardly through the foam producing member **436** and out the discharge outlet **17**. The pump **12** of FIG. **17** may have its housing **31** extend upwardly into a liquid containing reservoir, however, this is not necessary. As was the case with the pumps of this invention which dispense liquid upwardly, many different configurations of the liquid pump **70** may be used in downwardly dispensing pumps in substitution of the liquid pump **70** shown. Downwardly dispensing liquid pumps are known as taught, for example, in U.S. Pat. No. 5,165,577 to Ophardt, issued Nov. 24, 1992, the disclosure of which is incorporated herein by reference. The preferred embodiments illustrate the pumps **12** as being orientated with the central axis **23** vertical in each of the embodiments of FIGS. **1** to **17**. This is not necessary. In accordance with the present invention, the central axis **23** may be orientated to be horizontal or any angle between horizontal and vertical.

In the embodiments of FIGS. **1** to **16**, the terms “upper” and “lower” and “above” and “below” are used to describe the various orientations and in the names of elements with as considered axially along the axis relative the direction that fluid is dispensed from a reservoir such that “up” means “outer” and “down” means “inner” as seen in FIGS. **1** to **16**.

However, in FIG. **17**, the reverse applies with as considered axially along the axis relative the direction that fluid is dispensed from a reservoir such that "up" means "inner" and "down" means "outer" as seen in FIG. **17**. In the embodiments of FIGS. **1** to **16**, in referring to the various orientations and elements, the following words have the same meaning and may be substituted:

above=axially outwardly of
below=axially inwardly of
upper=outer
lower=inner
downwardly=axially inwardly
upwardly=axially outwardly.

For example, the lower end **24** may be referred to as the inner end **24**, and the first upper casing **201** may be referred to as the first outer casing **201**.

While the invention has been described with reference to preferred embodiments, many variations and modifications may now occur to a person skilled in the art. For a definition of the invention, reference is made to the following claims.

We claim:

1. A piston pump comprising:

a piston chamber-forming member (**20**) extending longitudinally about an axis (**23**) from an inner end (**24**) to an outer end (**25**);

the piston chamber-forming member (**20**) defining a central chamber (**26**) therein coaxially about the axis within an annular chamber wall (**27**);

the piston chamber-forming member having a liquid inlet (**28**) at the inner end (*24*) in communication with a liquid (**14**) in a reservoir (**13**);

a piston-forming element (**22**) coaxially slidably received within the chamber (**26**) in the piston chamber-forming member (**20**);

the piston-forming element (**22**) comprising an elongate tubular stem (**90**) with a central passageway (**63**) longitudinally therethrough, the passageway (**63**) extending from an inner end (**134**) *of the passageway* (*63*) to an outer end *of the passageway* (*63*);

the piston-forming element (**22**) coaxially slidable within the piston chamber-forming member (**20**) between an extended position and a retracted position in a cycle of operation comprising a withdrawal stroke and a retraction stroke to draw the liquid (**14**) from the reservoir (**13**) via the liquid inlet (**28**) and discharge the liquid mixed with air through the outer end of the passageway (**63**);

a liquid pump (**70**) formed between the piston chamber-forming member (**20**) and the piston-forming element (**22**) proximate the inner end **[134]** (*24*) of the piston chamber-forming member **[22]** (*20*),

the liquid pump (**70**) operative in the cycle of operation to draw the liquid from the reservoir (**13**) via the liquid inlet (**28**) and discharge the liquid into the passageway (**63**) proximate the inner end (**134**) of the passageway (**63**);

an inner air pump (**170**) formed between the piston chamber-forming member (**20**) and the piston-forming element (**22**) axially outwardly of the liquid pump (**70**) operative in the cycle of operation in **[a]** *the* withdrawal stroke to draw air from the atmosphere and in **[a]** *the* retraction stroke to discharge air into the passageway (**63**) through an inner air port (**142**) which extends radially inwardly through the stem (**90**) into the passageway (**63**);

a first outer air pump (**270**) formed between the piston chamber-forming member (**20**) and the piston-forming element (**22**) axially outwardly of the inner air pump (**170**),

the first outer air pump (**270**) operative in the cycle of operation in the withdrawal stroke to draw air from the atmosphere and in the retraction stroke to discharge air into the passageway (**63**) through a first outer air port (**162**) which extends radially inwardly through the stem (**90**) into the passageway **[91]** (*63*) at an axial location on the stem (**90**) spaced axially outwardly of the inner air port (**142**);

a first outer air sealing annular flange **[203]** (*231*) on the piston chamber-forming member (**20**) axially outwardly of the inner air pump (**170**),

the first outer air sealing annular flange **[203]** (*231*) extending from the chamber wall (**47**) radially inwardly to an annular distal edge (**232**) in engagement with a radially outwardly directed first outer cylindrical wall (**152**) on the stem **[91]** (*90*) axially inwardly of the first outer air port (**162**);

the annular distal edge (**232**) of the first outer air sealing annular flange **[203]** (*231*) engaging the first outer cylindrical wall (**152**) of the stem **[91]** (*90*) to prevent fluid flow axially inwardly therepast,

a first outer air sealing disc (**256**) on the stem **[91]** (*90*) axially outwardly of the first outer air port (**162**) and axially outwardly of the first outer air sealing annular flange **[203]** (*231*) on the piston chamber-forming member (**20**);

the first outer air sealing disc (**256**) extending radially outwardly from the stem **[91]** (*90*) to an annular distal edge (**257**) in engagement with a first cylindrical outer portion (**210**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member **[22]** (*20*) axially outwardly of the first outer air sealing annular flange **[203]** (*231*);

the annular distal edge (**257**) of the first outer air sealing disc (**256**) engaging the first cylindrical outer portion (**210**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) to prevent fluid flow axially **[upwardly]** *outwardly* therepast;

the first outer air pump (**270**) having a first outer air compartment (**271**) open to the first outer air port (**162**) and defined (a) annularly between the stem (**90**) of the piston-forming element (**22**) and the first cylindrical outer portion (**210**) of the chamber wall **[47]** (*27*) of the piston chamber-forming member (**20**), and (b) axially between the first outer air sealing annular flange **[203]** (*231*) and the first outer air sealing disc (**256**);

in **[a]** *the* cycle of operation in the withdrawal stroke, an axial distance between the first outer air sealing annular flange **[203]** (*231*) and the first outer air sealing disc (**256**) increases thereby increasing a volume of the first outer air compartment (**271**) and drawing air into the first outer air compartment (**271**) and, in the **[refraction]** *retraction* stroke, the axial distance between the first outer air sealing annular flange **[203]** (*231*) and the first outer air sealing disc (**256**) decreases thereby decreasing the volume of the first outer air compartment (**271**) and discharging air from the first outer air compartment (**271**) through the first outer air port (**162**) into the passageway (**63**).

2. A piston pump as claimed in claim **1** wherein:

the liquid pump (**70**) operative in **[a]** *the* cycle of operation in the withdrawal stroke to draw *the* liquid from the reservoir (**13**) via the liquid inlet (**28**) and, in the retraction stroke, to discharge *the* liquid into the passageway (**63**) proximate the inner end (**134**) of the passageway (**63**).

3. A piston pump as claimed in claim **1** including:

a second outer air pump (**370**) formed between the piston chamber-forming member (**20**) and the piston-forming element (**22**) axially outwardly of the first outer air pump (**270**),

the second outer air pump (**370**) operative in the cycle of operation in the withdrawal stroke to draw air from the atmosphere and, in the retraction stroke, to discharge air into the passageway (**63**) through a second outer air port (**262**) which extends radially inwardly through the stem (**90**) into the passageway (**63**) at an axial location on the stem (**90**) spaced axially outwardly of the first outer air port (**162**);

a second outer air sealing annular flange **[303]** (*331*) on the piston chamber-forming member **[20 above]** (*20*) *axially outwardly of* the first outer air pump (**270**), the second outer air sealing annular flange **[203]** (*331*) extending from the chamber wall **[47]** (*27*) radially inwardly to an annular distal edge (**332**) in engagement with a radially outwardly directed second outer cylindrical wall (**252**) on the stem (**90**) axially outwardly of the second outer air port (**262**);

the annular distal edge (**332**) of the second outer air sealing annular flange **[303]** (*331*) engaging the second outer cylindrical wall (**252**) of the stem (**90**) to prevent fluid flow axially inwardly therepast,

a second outer air sealing disc (**356**) on the stem (**90**) axially outwardly of the second outer air sealing annular flange **[303]** (*331*) on the piston chamber-forming member (**20**);

the second outer air sealing disc (**356**) extending radially outwardly from the stem (**90**) to an annular distal edge (**357**) in engagement with a second cylindrical outer portion (**310**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) axially outwardly of the second outer air sealing annular flange **[303]** (*331*);

the annular distal edge (**357**) of the second outer air sealing disc **[256]** (*356*) engaging the second cylindrical outer portion (**310**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) to prevent fluid flow axially outwardly therepast;

the second outer air pump (**370**) having a second outer air compartment (**371**) open to the second outer air port (**262**) and defined (a) annularly between the stem (**90**) of the piston-forming element (**22**) and the second cylindrical outer portion (**310**) of the chamber wall **[47]** (*27*) of the piston chamber-forming member (**20**), and (b) axially between the second outer air sealing annular flange **[303]** (*331*) and the second outer air sealing disc (**356**);

in **[a]** *the* cycle of operation in the withdrawal stroke, an axial distance between the second outer air sealing annular flange **[303]** (*331*) and the second outer air sealing disc (**356**) increases thereby increasing a volume of the second outer air compartment (**371**) and drawing air into the second outer air compartment (**371**) and, in the retraction stroke, the axial distance between the second outer air sealing annular flange **[303]** (*331*) and the second outer air sealing disc (**356**) decreases thereby decreasing the volume of the second outer air compartment (**371**) and discharging air from the second outer air compartment (**371**) through the second outer air port (**262**) into the passageway (**63**).

4. A piston pump as claimed in claim **3** wherein:

the first cylindrical outer portion (**210**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) extends axially between the first outer air sealing annular flange **[203]** (*231*) and the second outer air sealing annular flange **[303]** (*331*); and

the second cylindrical outer portion (**310**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) extends axially outwardly from the second outer air sealing annular flange **[303]** (*331*).

[5. A piston pump as claimed in claim **4** wherein:

the first outer air sealing annular flange **203** engages the second cylindrical outer portion **210** of the chamber wall **47** on the piston chamber-forming member **20** axially outwardly of the first outer air sealing disc **256** on the stem **90** and axially inwardly of the second outer air sealing disc **356** on the stem **90.]**

[6. A piston pump as claimed in claim **5** wherein:

a cylindrical first inner portion **110** of the chamber wall **47** on the piston chamber-forming member **20** extends axially inwardly from the first outer air sealing annular flange **203**;

a first inner air sealing disc **156** on the stem **90** axially inwardly of the first outwardly air sealing annular flange **203** on the piston chamber-forming member **20**;

the first inner air sealing disc **156** extending radially outwardly from the stem **90** to an annular distal edge **157** in engagement with the cylindrical first inner portion **110** of the chamber wall **47** on the piston chamber-forming member **20** axially inwardly of the first outer air sealing annular flange **203**;

the annular distal edge **157** of the first inner air sealing disc **156** engaging the first cylindrical inner portion **110** of the chamber wall **47** on the piston chamber-forming member **20** to prevent fluid flow axially upwardly therepast;

the inner air pump **170** having an inner air compartment **171** open to the inner air port **142** and defined (a) annularly between the stem **90** of the piston-forming element **22** and the first cylindrical inner portion **110** of the chamber wall **47** of the piston chamber-forming member **22**, and (b) axially inwardly of the first inner air sealing disc **156**;

in a cycle of operation in the withdrawal stroke, a volume of the inner air compartment **171** increases drawing air into the inner air compartment **171** and, in the retraction stroke, the volume of the inner air compartment **171** decreases discharging air from the inner air compartment **171** through the inner air port **142** into the passageway **63.]**

[7. A piston pump as claimed in claim **6** wherein:

a cylindrical second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** extends axially inwardly from the cylindrical first inner portion **110** of the chamber wall **47**, the cylindrical second inner portion **109** of the chamber wall **47** having a diameter less than a diameter of the cylindrical first inner portion **110** of the chamber wall **47**;

a second inner air sealing disc **140** on the stem **90** axially inwardly of the first outer air sealing annular flange **156** on the stem **90**,

the second inner air sealing disc **140** extending radially outwardly from the stem **90** to an annular distal edge **144** in engagement with the cylindrical second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20**;

the annular distal edge **144** of the second inner air sealing disc **140** engaging the second cylindrical inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** to prevent fluid flow axially inwardly therepast;

an inner air compartment **142** defined (a) annularly between the stem **90** of the piston-forming element **22** and the first cylindrical inner portion **110** and the second cylindrical inner portion **109** of the chamber wall **47** of the piston chamber-forming member **20**, and (b) axially between the first inner air sealing annular flange **156** and the second inner air sealing disc **140**.**]**

[8. A piston pump as claimed in claim **7** wherein:

a liquid sealing disc **139** on the stem **90** axially inwardly of the first inner air sealing disc **140**;

the liquid sealing disc **139** extending radially outwardly from the stem **90** to an annular distal edge **145** in engagement with the cylindrical second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** axially inwardly of the second inner air sealing disc **140**;

the annular distal edge **145** of the liquid sealing disc **139** engaging the second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** to prevent fluid flow axially inwardly therepast;

the liquid sealing disc **139** being resilient and having an inherent bias biasing the annular distal edge **145** into engagement with the second inner portion **109** of the chamber wall **47** and deflectable against the bias from engagement with the second inner portion **109** of the chamber wall **47** to permit liquid fluid flow axially outwardly therepast when a pressure differential between a pressure on an inner axial side of the liquid sealing disc **139** is sufficiently greater than a pressure on an inner axial side of the liquid sealing disc **139**;

a one-way valve **102** across the liquid inlet **28** permitting fluid flow therepast from the reservoir **13** into the chamber **26** and preventing fluid flow therepast from the chamber **26** into the reservoir **13**,

a liquid port **141** on the stem **90** axially between the liquid sealing disc **139** and the second inner air sealing disc **140**;

the liquid port **141** extending radially inwardly through the stem **90** into the passageway **63**;

the liquid pump **70** having a liquid compartment **106** open to the liquid port **141** and defined (a) annularly between the stem **90** of the piston-forming element **22** and the second inner portion **109** of the chamber wall **47** of the piston chamber-forming member **20**, and (b) axially inwardly of the liquid sealing disc **139** between the liquid sealing disc **139** and the one-way valve **102**;

in the cycle of operation in the withdrawal stroke, a volume of the liquid compartment **106** increases drawing liquid past the one-way valve **102** from the reservoir **13** into the liquid compartment **106** and, in the retraction stroke, the volume of the liquid compartment **106** decreases discharging liquid from the liquid compartment **106** past the liquid sealing disc **139** to between the liquid sealing disc **139** and the second inner air sealing disc **140** and through the liquid port **141** into the passageway **63**.**]**

[9. A piston pump as claimed in claim **8** wherein:

the inner air pump **170** having a cylindrical inner air pump wall **110** provided by the piston chamber-forming member **20**,

a first inner air sealing disc **156** extending radially outwardly on the stem **90** axially outwardly of the inner air port **142** for sealing engagement with the inner air pump wall **110**;

the first outer air sealing disc **256** extending radially outwardly on the stem **90** axially outwardly of the first inner air sealing disc **156** of the inner air pump **170**;

the first outer air sealing annular flange **203** on the piston chamber-forming member **20** being axially outwardly of the first inner air sealing disc **156** of the inner air pump **170**,

the first outer air sealing annular flange **203** extending radially inwardly for sealing engagement with the radially outwardly directed stem wall **152** of the stem **90** axially outwardly of the first inner air sealing disc **156** of the inner air pump **170**;

the first inner air sealing disc **156** extending radially outwardly on the stem **90** above the second inner air sealing disc **140** of the inner air pump **170** into sealing engagement with the cylindrical outer air pump wall **110** provided by the piston chamber-forming member **20** axially inwardly of the outer air sealing annular flange **203**.**]**

[10. A piston pump as claimed in claim **9** wherein:

the piston-forming element **22** comprises:

a liquid piston **130** having a hollow tubular stem **131** with the inner end **134** and an outer end **135** and a central passage **133** longitudinally therethrough about the axis **23**,

an inner air piston **150** having a hollow tubular stem **151** with an inner end **154** and an outer end **155** and a central passage **153** longitudinally therethrough about the axis **23**, and

a first outer air piston **250** having a hollow tubular stem **251** with an inner end **254** and the outer end **255** and a central passage **253** longitudinally therethrough about the axis **23**,

the liquid piston **130**, the inner air piston **150** and the first outer air piston **250** coaxially disposed about the axis **23** with:

(a) the outer end **135** of the liquid piston **130** coupled to the inner end **154** of the inner air piston **150** and the outer end **155** of the inner air piston **150** coupled to the inner end **254** of the first outer air piston **250**, and

(b) the central passage **133** of the liquid piston **130** opening axially into the central passage **153** of the inner air piston **150** and the central passage **153** of the inner air piston **150** opening axially into the central passage **253** of the first outer air piston **250** forming the central passageway **63** through the liquid piston **130**, the inner air piston **150** and the first outer air piston **250**,

the first outer air sealing disc **256** carried on the inner end **254** of the first outer air piston **250** extending radially outwardly from the stem **251**;

the first outer air port **162** on the inner air piston **150** proximate but axially inwardly of the first outer air sealing disc **256**,

the piston chamber-forming member **20** comprising:

a hollow tubular inner casing **101** having the end **24** and an outer end **105**, and

a hollow tubular first outer casing **201** having an inner end **204** and the outer end **205**;

the inner casing **101** defining a liquid chamber **106** and an inner air chamber **107** therein, the liquid chamber **106** axially open to the inner end **24** of the inner casing **101** and opening axially inwardly into the inner air chamber **107** which is open to the outer end **105** of the inner casing **101**;

the first outer casing **201** defining a first outer air chamber **207** therein,

the inner casing **101** and the first outer casing **210** coaxially disposed about the axis **23** with:

(a) the outer end **105** of the inner casing **101** coupled to the inner end **204** of the first outer casing **201**, and

(b) the inner air chamber **107** opening axially into the first outer air chamber **207**;

the first annular air sealing flange **203** coaxially carried by the first outer casing **201** fixed to the first outer casing **201** at the inner end **204** of the first outer casing **201**,

the stem **151** of the inner air piston **150** passing coaxially through the first annular air sealing flange **203** axially inwardly of the first outer air sealing disc **256**,

the first annular air sealing flange **203** extending radially inwardly from sealed engagement with the first outer casing **201** into engagement with the stem **151** of the inner air piston **150** axially inwardly of the first outer air port **162**,

the first outer air chamber **207** defined in an annular space radially inside the first outer casing **201** between the first outer casing **201** and the stem **151** of the inner air piston **150** and axially between first annular air sealing flange **203** and the first outer air sealing disc **256**,

the first outer air chamber **207** open via the first outer air port **162** into the passageway **153**.**]**

11. A piston pump as claimed in claim **4** wherein:

the piston-forming element (**22**) comprises:

a liquid piston (**130**) having a hollow tubular stem (**131**) with the inner end (**134**) and an outer end (**135**) and a central passage (**133**) longitudinally therethrough about the axis (**23**),

an inner air piston (**150**) having a hollow tubular stem (**151**) with an inner end (**154**) and an outer end (**155**) and a central passage (**153**) longitudinally therethrough about the axis (**23**), and

a first outer air piston (**250**) having a hollow tubular stem (**251**) with an inner end (**254**) and **[**the**]** *an* outer end (**255**) and a central passage (**253**) longitudinally therethrough about the axis (**23**),

a second outer air piston (**350**) having a hollow tubular stem (**351**) with an inner end (**354**) and an outer end (**355**) and a central passage (**353**) longitudinally therethrough about the axis (**23**),

the liquid piston (**130**), the inner air piston (**150**), the first outer air piston (**250**) and the second outer air piston (**350**) coaxially disposed about the axis (**23**) with:

(a) the outer end (**135**) of the liquid piston (**130**) coupled to the inner end (**154**) of the inner air piston (**150**), the outer end (**155**) of the inner air piston (**150**) coupled to the inner end (**254**) of the first outer air piston (**250**), and the outer end of the first outer air piston (**250**) coupled to the inner end (*354*) of the second outer air piston (**350**), and

(b) the central passage (**133**) of the liquid piston (**130**) opening axially into the central passage (**153**) of the inner air piston (**150**),

the central passage (**153**) of the inner air piston (**150**) opening axially into the central passage (**253**) of the first outer air piston (**250**) and the central passage of the first outer air piston opening axially into the central passage of the second outer air piston forming the central passageway (**63**) through the liquid piston (**130**), the inner air piston (**150**), the first outer air piston (**250**) and the second outer air piston (**350**),

the first outer air sealing disc (**256**) carried on the inner end (**254**) of the first outer air piston (**250**) extending radially outwardly from the stem (**251**),

the second outer air sealing disc (**356**) carried on the inner end (**354**) of the second outer air piston (**350**) extending radially outwardly from the stem (**351**),

the first outer air port (**162**) on the inner air piston (**150**) proximate but axially inwardly of the first outer air sealing disc (**256**),

the second outer air port (**262**) on the first outer air piston (**250**) proximate but axially inwardly of the second outer air sealing disc (**356**),

the piston chamber-forming member (**20**) comprising:

a hollow tubular inner casing (**101**) having the inner end (**24**) and an outer end (**105**), a hollow tubular first outer casing (**201**) having an inner end (**204**) and **[**the**]** *an* outer end (**205**); and a hollow tubular second outer casing (**301**) having an inner end (**304**) and an outer end (**305**);

the inner casing (**101**) defining a liquid chamber (**106**) and an inner air chamber (**107**) therein, the liquid chamber (**106**) axially open to the inner end (**24**) of the inner casing (**101**) and opening axially inwardly into the inner air chamber (**107**) which is open to the outer end (**105**) of the inner casing (**101**);

the first outer casing (**201**) defining a first outer air chamber (**207**) therein, the second outer casing (**301**) defining a second outer air chamber (**307**) therein;

the inner casing (**101**), the first outer casing (**201**) and the second outer casing (**301**) coaxially disposed about the axis (**23**) with:

(a) the outer end (**105**) of the inner casing (**101**) coupled to the inner end (**204**) of the first outer casing (**201**),

(b) the inner air chamber (**107**) opening axially into the first outer air chamber (**207**), and

(c) the first outer air chamber (**207**) opening axially into the second outer air chamber (**307**);

the first **[**annular**]** *outer* air sealing *annular* flange **[203]** (*231*) coaxially carried by the first outer casing (**201**) fixed to the first outer casing (**201**) at the inner end (**204**) of the first outer casing (**201**),

the stem (**151**) of the inner air piston (**150**) passing coaxially through the first **[**annular**]** *outer* air sealing *annular* flange **[203]** (*231*) axially inwardly of the first outer air sealing disc (**256**),

the first **[**annular**]** *outer* air sealing *annular* flange **[203]** (*231*) extending radially inwardly from sealed engagement with the first outer casing (**201**) into engagement with the stem (**151**) of the inner air piston (**150**) axially inwardly of the first outer air port (**162**),

the first outer air chamber (**207**) defined in an annular space radially inside the first outer casing (**201**) between the first outer casing (**201**) and the stem (**151**) of the inner air piston (**150**) and axially between first **[**annular**]** *outer* air sealing *annular* flange **[203]** (*231*) and the first outer air sealing disc (**256**),

the first outer air chamber (**207**) open via the first outer air port (**162**) into the passageway (**153**),

the second **[**annular**]** *outer* air sealing *annular* flange **[303]** (*331*) coaxially carried by the second outer casing (**301**) fixed to the second outer casing (**301**) at the inner end (**304**) of the second **[**first**]** outer casing (**301**),

the stem (**251**) of the first outer air piston (**250**) passing coaxially through the second **[**annular**]** *outer* air sealing *annular* flange **[303]** (*331*) axially inwardly of the second outer air sealing disc (**356**),

the second **[**annular**]** *outer* air sealing *annular* flange **[303]** (*331*) extending radially inwardly from sealed engagement with the second outer casing (**301**) into engagement with the stem (**251**) of the first outer air piston (**250**) axially inwardly of the second outer air port (**262**),

the second outer air chamber (**307**) defined in an annular space radially inside the second outer casing (**301**) between the second **[**first**]** outer casing (**301**) and the stem (**251**) of the first outer air piston (**250**) and axially between the second **[**annular**]** *outer* air sealing *annular* flange **[303]** (*331*) and the second outer air sealing disc (**356**), the second outer air chamber (**307**) open via the second outer air port (**262**) into the passageway (**253**).

12. A piston pump as claimed in claim **11** wherein the inner air piston (**150**) and the first outer air piston (**250**) are identical modular elements.

13. A piston pump as claimed in claim **11** wherein the first outer casing (**201**) and the second outer casing (**301**) are identical modular elements.

14. A piston pump as claimed in claim **1** wherein: a cylindrical first inner portion (**110**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) extends axially inwardly from the first outer air sealing annular flange **[203]** (*231*);

a first inner air sealing disc (**156**) on the stem (**90**) axially inwardly of the first **[**outwardly**]** *outer* air sealing annular flange **[203]** (*231*) on the piston chamber-forming member (**20**);

the first inner air sealing disc (**156**) extending radially outwardly from the stem (**90**) to an annular distal edge (**157**) in engagement with the cylindrical first inner portion (**110**) of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) axially inwardly of the first outer air sealing annular flange **[203]** (*231*);

the annular distal edge (**157**) of the first inner air sealing disc (**156**) engaging the **[**first**]** cylindrical *first* inner portion **110** of the chamber wall **[47]** (*27*) on the piston chamber-forming member (**20**) to prevent fluid flow axially outwardly therepast;

the inner air pump (**170**) having an inner air compartment (**171**) open to the inner air port **142** and defined (a) annularly between the stem (**90**) of the piston-forming element (**22**) and the first cylindrical inner portion (**110**) of the chamber wall **[47]** (*27*) of the piston chamber-forming member **[22]** (*20*), and (b) axially inwardly of the first inner air sealing disc (**156**); in **[**a**]** *the* cycle of operation in the withdrawal stroke, a volume of the inner air compartment (**171**) increases drawing air into the inner air compartment (**171**) and, in the retraction stroke, the volume of the inner air compartment (**171**) decreases discharging air from the inner air compartment (**171**) through the inner air port (**142**) into the passageway (**63**).

[15. A piston pump as claimed in claim **14** wherein:

a cylindrical second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** extends axially inwardly from the cylindrical first inner portion **110** of the chamber wall **47**, the cylindrical second inner portion **109** of the chamber wall **47** having a diameter less than a diameter of the cylindrical first inner portion **110** of the chamber wall **47**;

a second inner air sealing disc **140** on the stem **90** axially inwardly of the first outer air sealing annular flange **156** on the stem **90**,

the second inner air sealing disc **140** extending radially outwardly from the stem **90** to an annular distal edge **144** in engagement with the cylindrical second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20**;

the annular distal edge **144** of the second inner air sealing disc **140** engaging the second cylindrical inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** to prevent fluid flow axially inwardly therepast;

an inner air compartment **142** defined (a) annularly between the stem **90** of the piston-forming element **22** and the first cylindrical inner portion **110** and the second cylindrical inner portion **109** of the chamber wall **47** of the piston chamber-forming member **20**, and (b) axially between the first inner air sealing annular flange **156** and the second inner air sealing disc **140**.**]**

[16. A piston pump as claimed in claim **15** wherein:

a liquid sealing disc **139** on the stem **90** axially inwardly of the first inner air sealing disc **140**;

the liquid sealing disc **139** extending radially outwardly from the stem **90** to an annular distal edge **145** in engagement with the cylindrical second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** axially inwardly of the second inner air sealing disc **140**;

the annular distal edge **145** of the liquid sealing disc **139** engaging the second inner portion **109** of the chamber wall **47** on the piston chamber-forming member **20** to prevent fluid flow axially inwardly therepast;

the liquid sealing disc **139** being resilient and having an inherent bias biasing the annular distal edge **145** into engagement with the second inner portion **109** of the chamber wall **47** and deflectable against the bias from engagement with the second inner portion **109** of the chamber wall **47** to permit liquid fluid flow axially outwardly therepast when a pressure differential between a pressure on an inner axial side of the liquid sealing disc **139** is sufficiently greater than a pressure on an inner axial side of the liquid sealing disc **139**;

a one-way valve **102** across the liquid inlet **28** permitting fluid flow therepast from the reservoir **13** into the chamber **26** and preventing fluid flow therepast from the chamber **26** into the reservoir **13**,

a liquid port **141** on the stem **90** axially between the liquid sealing disc **139** and the second inner air sealing disc **140**;

the liquid port **141** extending radially inwardly through the stem **90** into the passageway **63**;

the liquid pump **70** having a liquid compartment **106** open to the liquid port **141** and defined (a) annularly between the stem **90** of the piston-forming element **22** and the second inner portion **109** of the chamber wall **47** of the piston chamber-forming member **20**, and (b) axially inwardly of the liquid sealing disc **139** between the liquid sealing disc **139** and the one-way valve **102**;

in the cycle of operation in the withdrawal stroke, a volume of the liquid compartment **106** increases drawing liquid past the one-way valve **102** from the reservoir **13** into the liquid compartment **106** and, in the retraction stroke, the volume of the liquid compartment **106** decreases discharging liquid from the liquid compartment **106** past the liquid sealing disc **139** to between the liquid sealing disc **139** and the second inner air sealing disc **140** and through the liquid port **141** into the passageway **63**.**]**

[**17**. A piston pump as claimed in claim **1** wherein:
the inner air pump **170** having a cylindrical inner air pump wall **110** provided by the piston chamber-forming member **20**,
a first inner air sealing disc **156** extending radially outwardly on the stem **90** axially outwardly of the inner air port **142** for sealing engagement with the inner air pump wall **110**;
the first outer air sealing disc **256** extending radially outwardly on the stem **90** axially outwardly of the first inner air sealing disc **156** of the inner air pump **170**;
the first outer air sealing annular flange **203** on the piston chamber-forming member **20** being axially outwardly of the first inner air sealing disc **156** of the inner air pump **170**,
the first outer air sealing annular flange **203** extending radially inwardly for sealing engagement with the radially outwardly directed stem wall **152** of the stem **90** axially outwardly of the first inner air sealing disc **156** of the inner air pump **170**;
the first inner air sealing disc **156** extending radially outwardly on the stem **90** axially outwardly of the second inner air sealing disc **140** of the inner air pump **170** into sealing engagement with the cylindrical outer air pump wall **110** provided by the piston chamber-forming member **20** axially inwardly of the outer air sealing annular flange **203**.]

18. A piston pump as claimed in claim **1** wherein:
the piston-forming element (**22**) comprises:
a liquid piston (**130**) having a hollow tubular stem (**131**) with the inner end (**134**) and an outer end (**135**) and a central passage (**133**) longitudinally therethrough about the axis (**23**),
an inner air piston (**150**) having a hollow tubular stem (**151**) with an inner end (**154**) and an outer end (**155**) and a central passage (**153**) longitudinally therethrough about the axis (**23**), and a first outer air piston (**250**) having a hollow tubular stem (**251**) with an inner end (**254**) and [the] *an* outer end (**255**) and a central passage (**253**) longitudinally therethrough about the axis (**23**),
the liquid piston (**130**), the inner air piston (**150**) and the first outer air piston (**250**) coaxially disposed about the axis (**23**) with:
(a) the outer end (**135**) of the liquid piston (**130**) coupled to the inner end (**154**) of the inner air piston (**150**) and the outer end (**155**) of the inner air piston (**150**) coupled to the inner end (**254**) of the first outer air piston (**250**), and
(b) the central passage (**133**) of the liquid piston (**130**) opening axially into the central passage (**153**) of the inner air piston (**150**) and the central passage (**153**) of the inner air piston (**150**) opening axially into the central passage (**253**) of the first outer air piston (**250**) forming the central passageway (**63**) through the liquid piston (**130**), the inner air piston (**150**) and the first outer air piston (**250**), the first outer air sealing disc (**256**) carried on the inner end (**254**) of the first outer air piston (**250**) extending radially outwardly from the stem (**251**);
the first outer air port (**162**) on the inner air piston (**150**) proximate but axially inwardly of the first outer air sealing disc (**256**),
the piston chamber-forming member (**20**) comprising:
a hollow tubular inner casing (**101**) having the *inner* end (**24**) and an outer end (**105**), and a hollow tubular first outer casing (**201**) having an inner end (**204**) and [the] *an* outer end (**205**);
the inner casing (**101**) defining a liquid chamber (**106**) and an inner air chamber (**107**) therein,
the liquid chamber (**106**) axially open to the inner end (**24**) of the inner casing (**101**) and opening axially inwardly into the inner air chamber (**107**) which is open to the outer end (**105**) of the inner casing (**101**);
the first outer casing (**201**) defining a first outer air chamber (**207**) therein, the inner casing (**101**) and the first outer casing (**210**) coaxially disposed about the axis (**23**) with:
(a) the outer end (**105**) of the inner casing (**101**) coupled to the inner end (**204**) of the first outer casing (**201**), and
(b) the inner air chamber (**107**) opening axially into the first outer air chamber (**207**),
the first [annular] *outer* air sealing *annular* flange [**203**] (*231*) coaxially carried by the first outer casing (**201**) fixed to the first outer casing (**201**) at the inner end (**204**) of the first outer casing (**201**),
the stem (**151**) of the inner air piston (**150**) passing coaxially through the first [annular] *outer* air sealing *annular* flange [**203**] (*231*) axially inwardly of the first outer air sealing disc (**256**),
the first [annular] *outer* air sealing *annular* flange [**203**] (*231*) extending radially inwardly from sealed engagement with the first outer casing (**201**) into engagement with the stem (**151**) of the inner air piston (**150**) axially inwardly of the first outer air port (**162**),
the first outer air chamber (**207**) defined in an annular space radially inside the first outer casing (**201**) between the first outer casing (**201**) and the stem (**151**) of the inner air piston (**150**) and axially between first [annular] *outer* air sealing *annular* flange [**203**] (*231*) and the first outer air sealing disc (**256**),
the first outer air chamber (**207**) open via the first outer air port (**162**) into the passageway (**153**).

19. A piston pump as claimed in claim **18** wherein a cross-sectional area of the passageway (**63**) normal the axis varies along the axis.

20. A piston pump as claimed in claim **1** including a foam generator in the passageway (**63**) to mix the air and the liquid passing outwardly therethrough to produce foam.

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