United States Patent [19]

Laub, III

[11] **3,870,089**

[45] **Mar. 11, 1975**

[54] **ANTIDRIP VOLUMETRIC RAPID FILLING MACHINE**

[76] Inventor: **Herman Laub, III,** 244 N. San Marino, San Gabriel, Calif. 91775

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[21] Appl. No.: **261,913**

[52] **U.S. Cl.** **141/44,** 141/94, 141/115, 141/158, 141/160, 141/367

[51] **Int. Cl.** **B65b 3/12,** B65b 31/04, B65b 57/08

[58] **Field of Search** 141/37, 44–46, 141/48, 59, 61, 65, 85–88, 93, 94, 99, 126, 138–152, 156–162, 177, 351, 352, 360, 362, 369, 372, 374, 115, 367; 137/202; 222/249, 250

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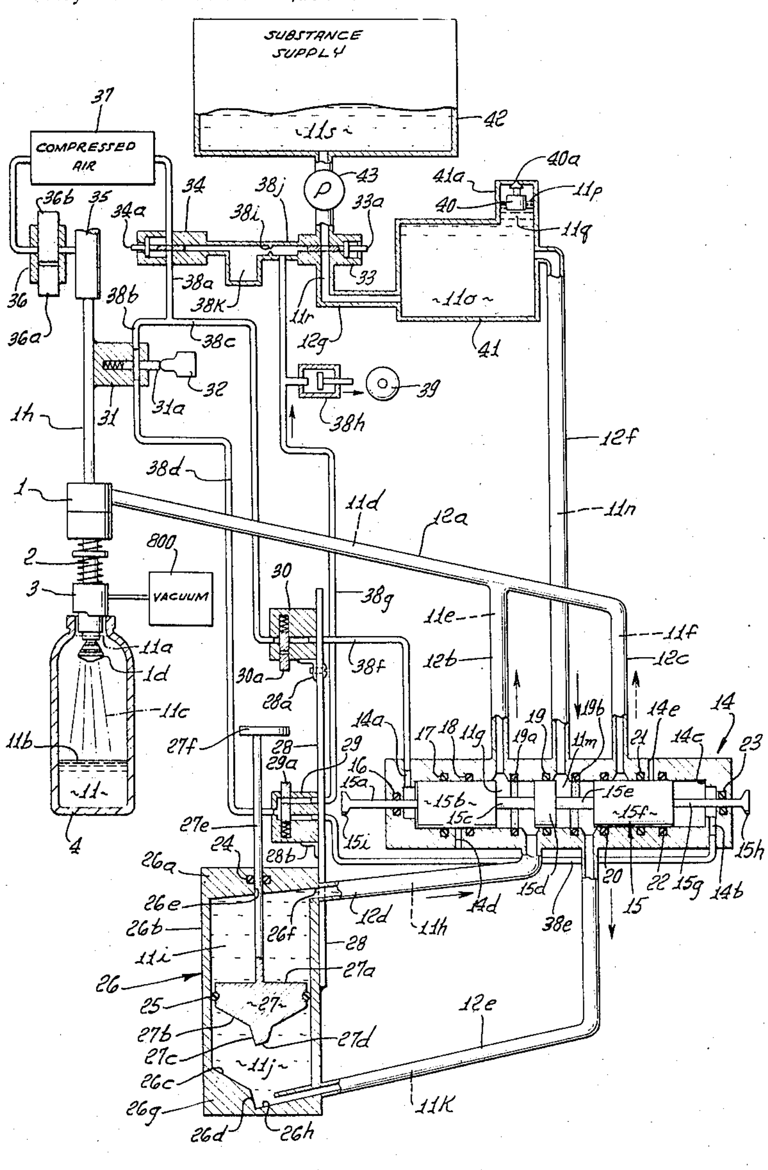
Assistant Examiner—Frederick R. Schmidt
Attorney, Agent, or Firm—Peter I. Lippman

[57] **ABSTRACT**

This device for rapid and extremely accurate filling of bottles includes a volumetric bi-acting piston, a submersible filling nozzle which opens only when it is actually dispensing and which carries an antidrip suction mechanism adapted to draw off only air above the fluid level when it is not picking up drips from the nozzle tip, provisions for control to avoid dispensing operations when no bottle is present in receiving position, and adjustability of volume and flow rate individually and volume in common for all filling heads in a multiple-head system — all without stopping the filler. Also included are provisions for preventing entrainment of air in the system, and for removing any air which is originally trapped in the system at startup or through operation of a supply pump.

46 Claims, 15 Drawing Figures



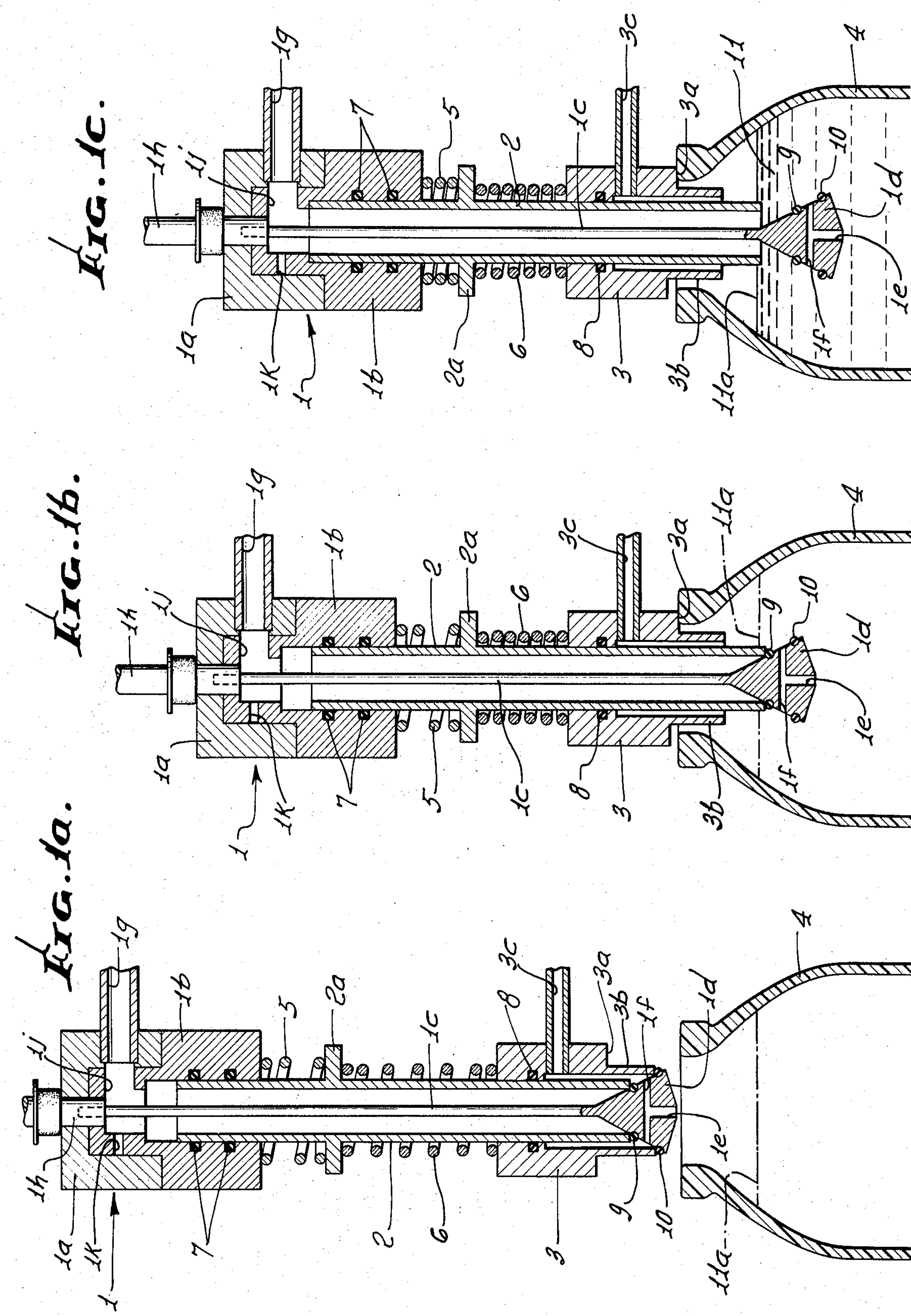


FIG. 1a.

FIG. 1b.

FIG. 1c.

FIG. 2.

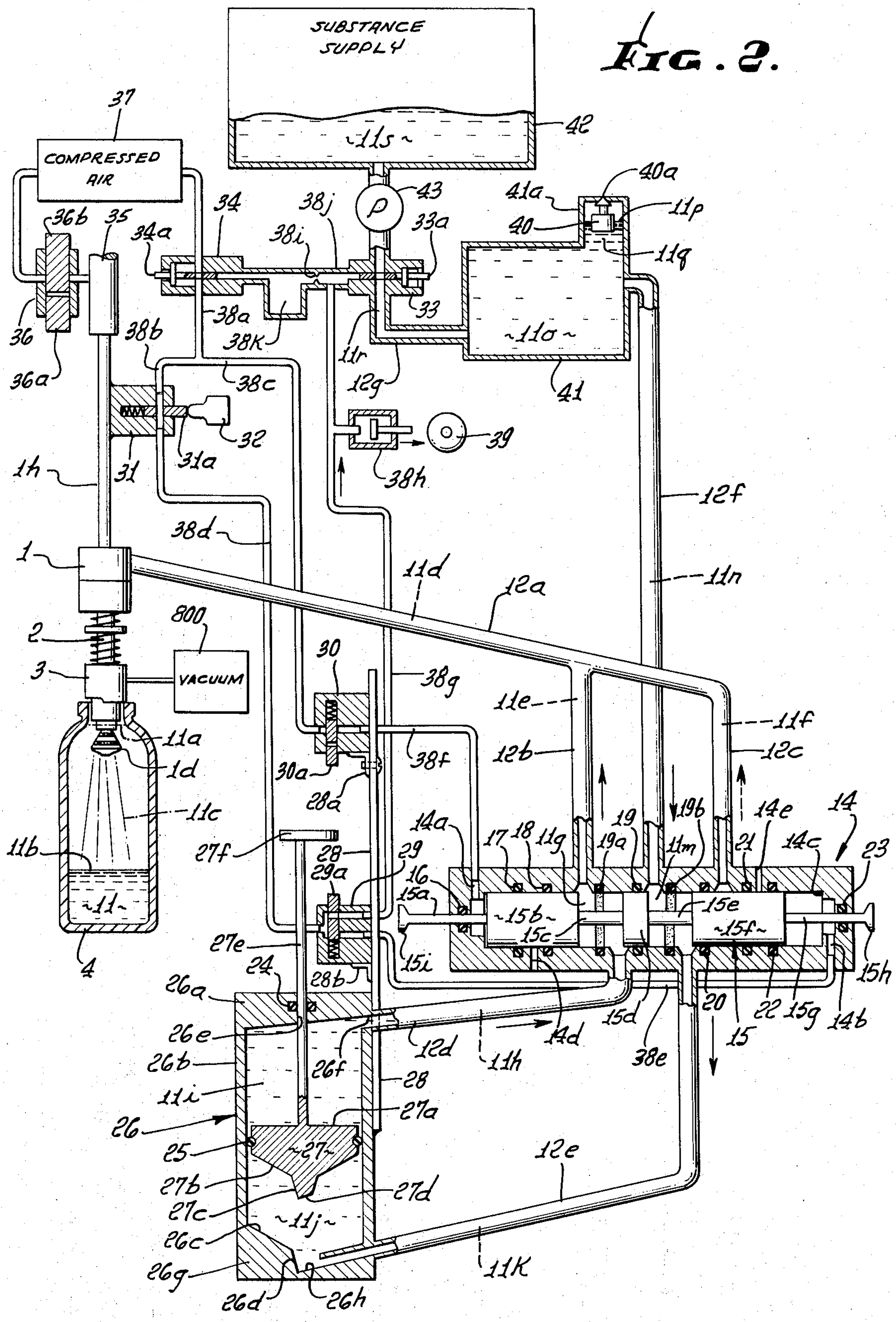


FIG. 2a.

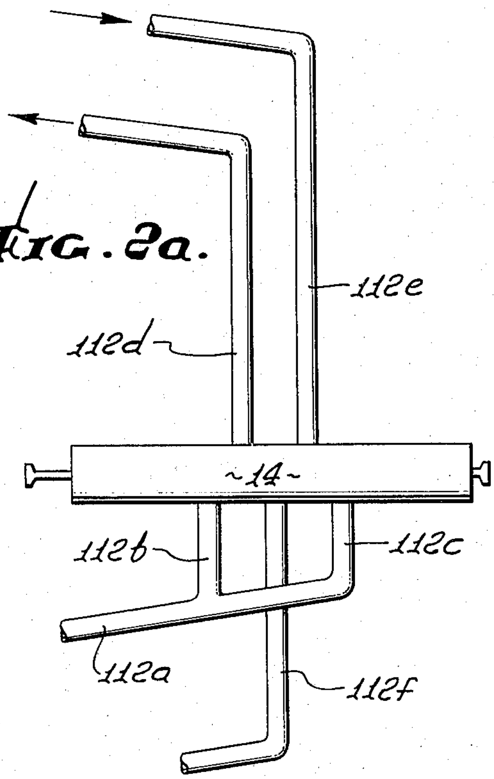


FIG. 2b.

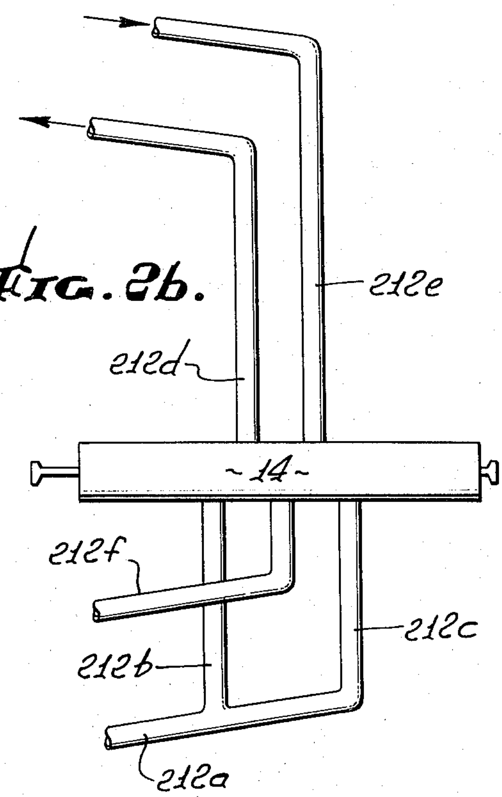


FIG. 2c.

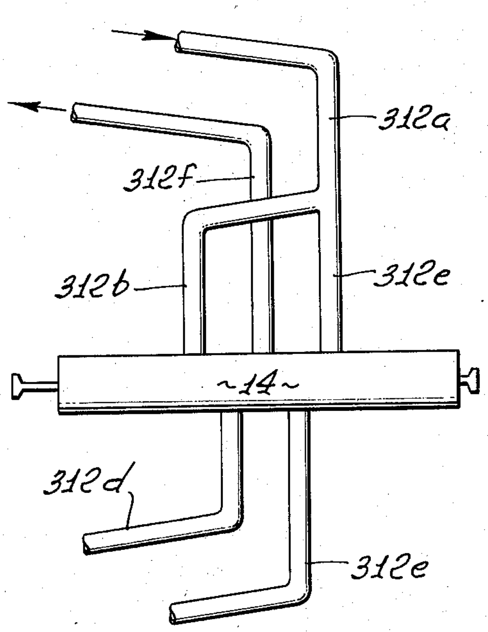


FIG. 2d.

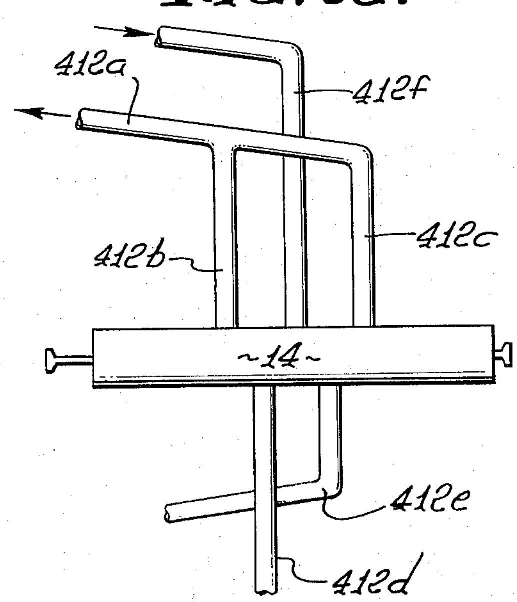


FIG. 3a.

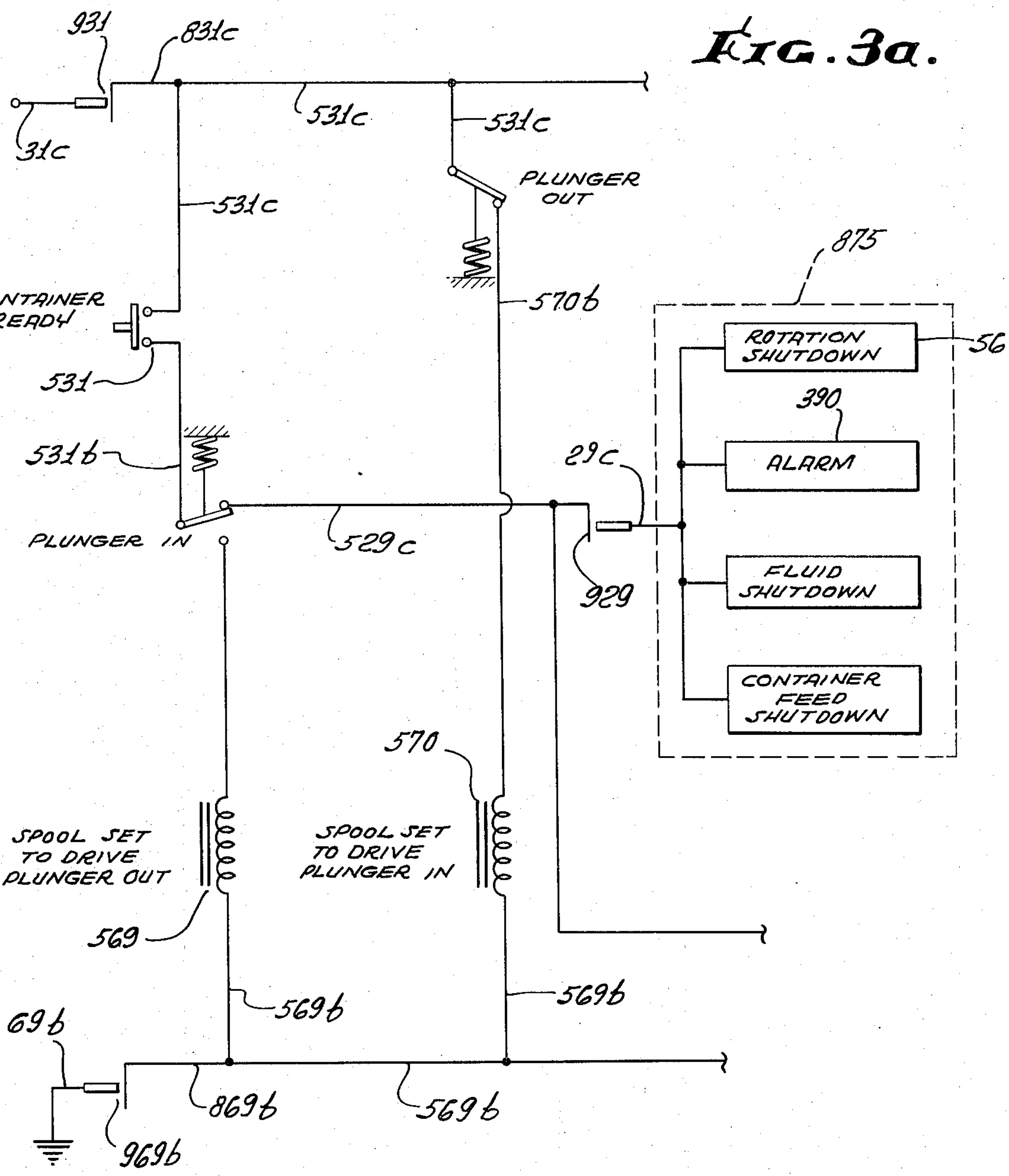

931
831c
31c
531c
531c
531c
PLUNGER OUT
570b
875
ROTATION SHUTDOWN
56
CONTAINER READY
531
390
ALARM
531b
29c
PLUNGER IN
529c
929
FLUID SHUTDOWN
CONTAINER FEED SHUTDOWN
570
SPOOL SET TO DRIVE PLUNGER OUT
SPOOL SET TO DRIVE PLUNGER IN
569
569b
569b
69b
869b
569b
969b

FIG. 2e.

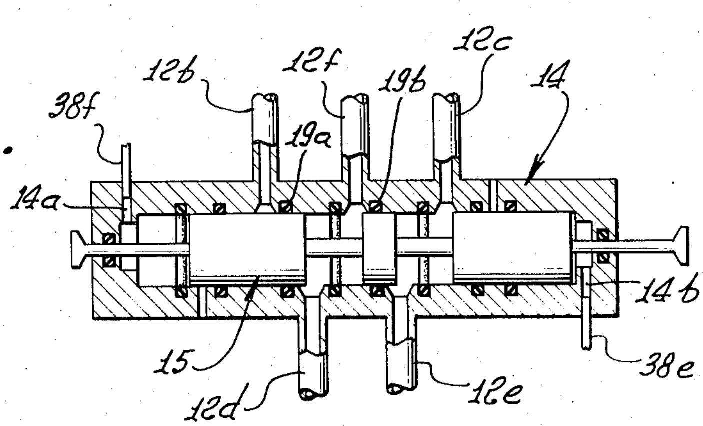

12b
12f
19b
12c
14
38f
19a
14a
14b
15
38e
12d
12e

FIG. 3.

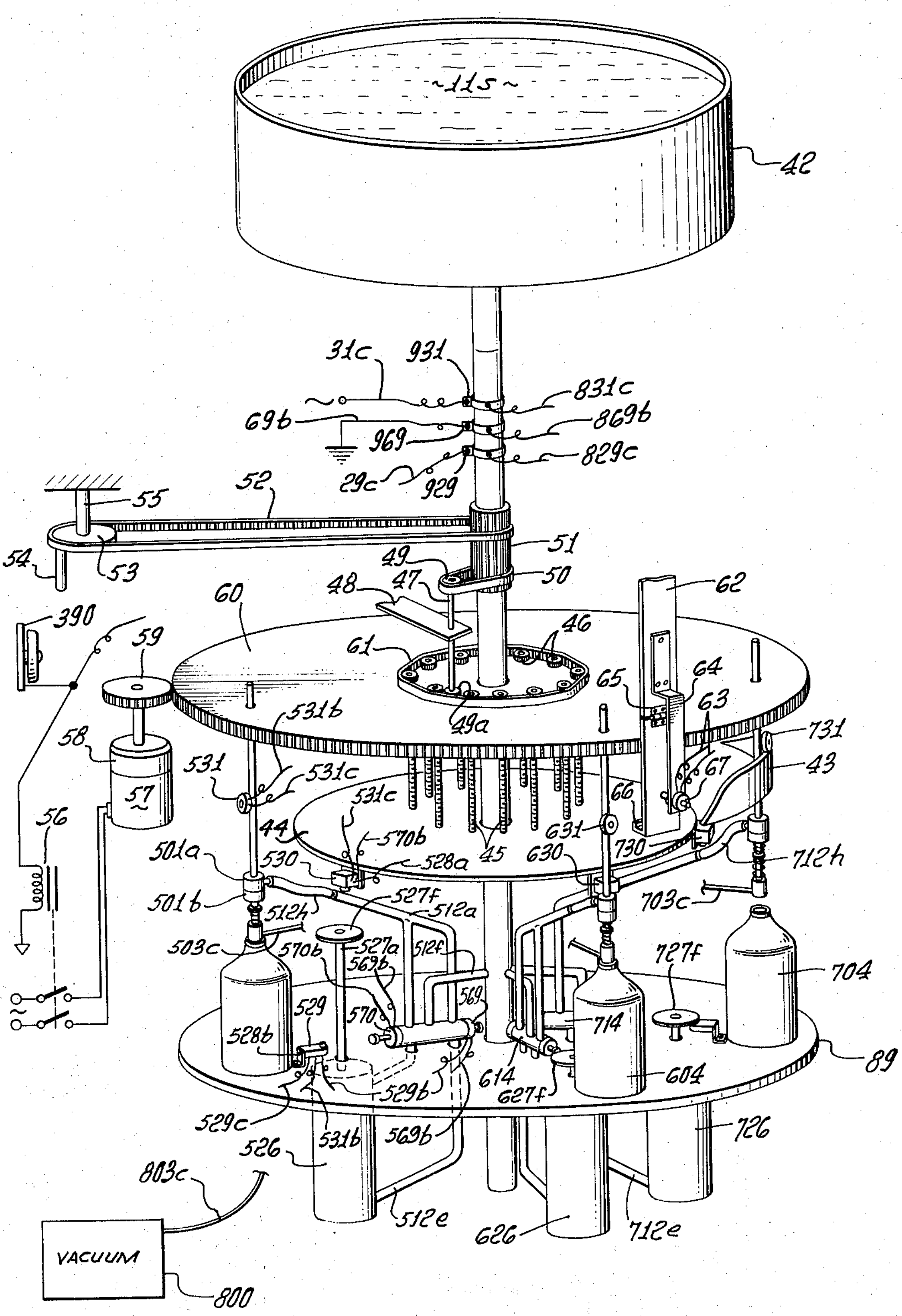
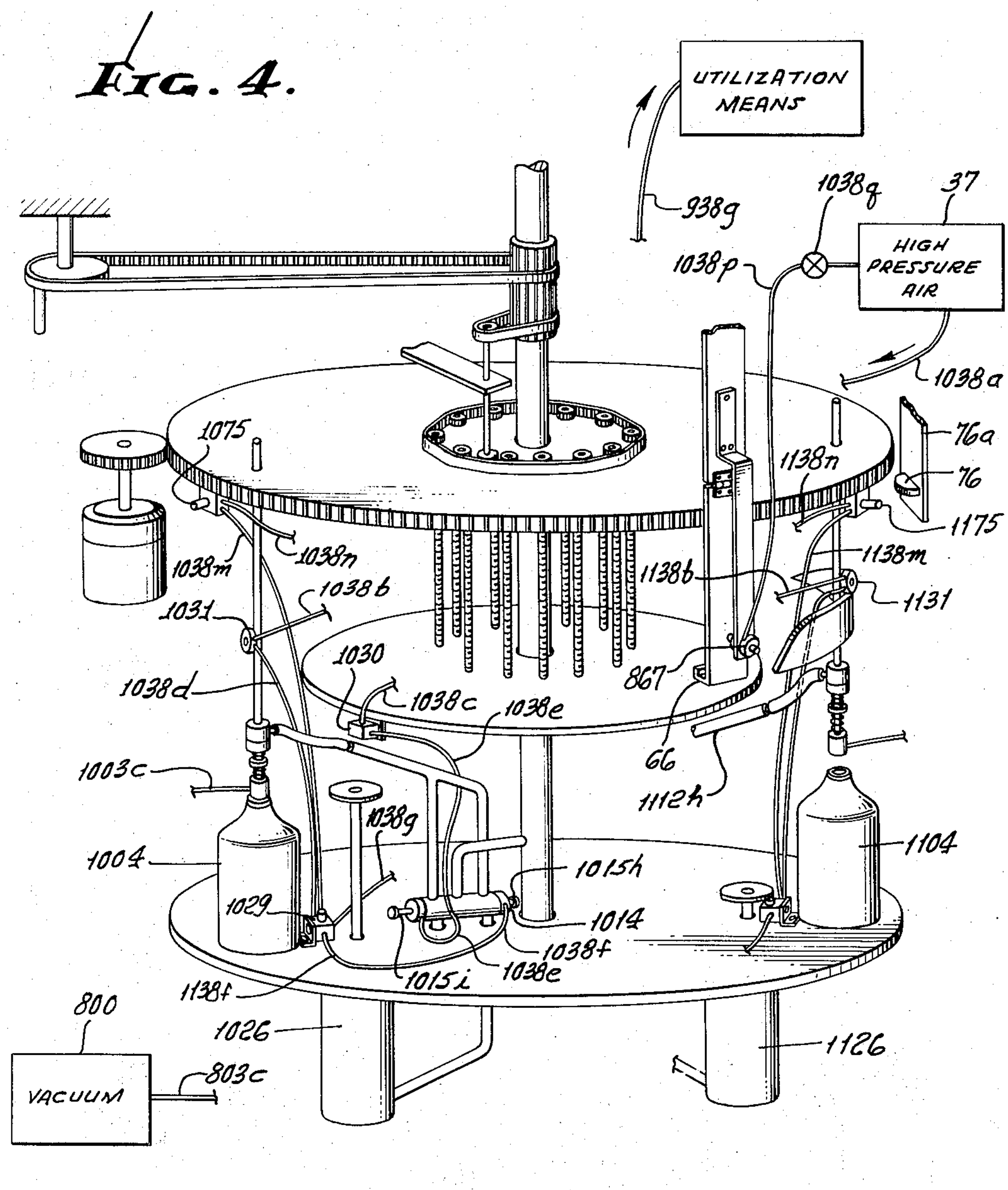

115
42
31c
931
831c
69b
869b
969
829c
29c
929
52
55
54
53
51
49
50
47
48
60
62
46
390
59
61
65
64
49a
58
531b
63
731
43
531
531c
67
57
56
531c
570b
66
631
44
45
630
730
501a
530
528a
712h
501b
527f
512a
703c
512h
503c
570b
527a
569b
512f
727f
704
529
570
569
714
528b
614
604
89
529b
627f
529c
531b
569b
726
526
803c
512e
626
712e
VACUUM
800

FIG. 4.


UTILIZATION MEANS
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1038q
37
HIGH PRESSURE AIR
1038p
1038a
76a
76
1175
1075
1138n
1138m
1131
1138b
1038m
1038n
1038b
1031
1038d
1030
1038c
1038e
867
66
1112h
1003c
1004
1038g
1104
1029
1015h
1014
1038f
1015i
1038e
1138f
800
1026
1126
VACUUM
803c

FIG. 4a.

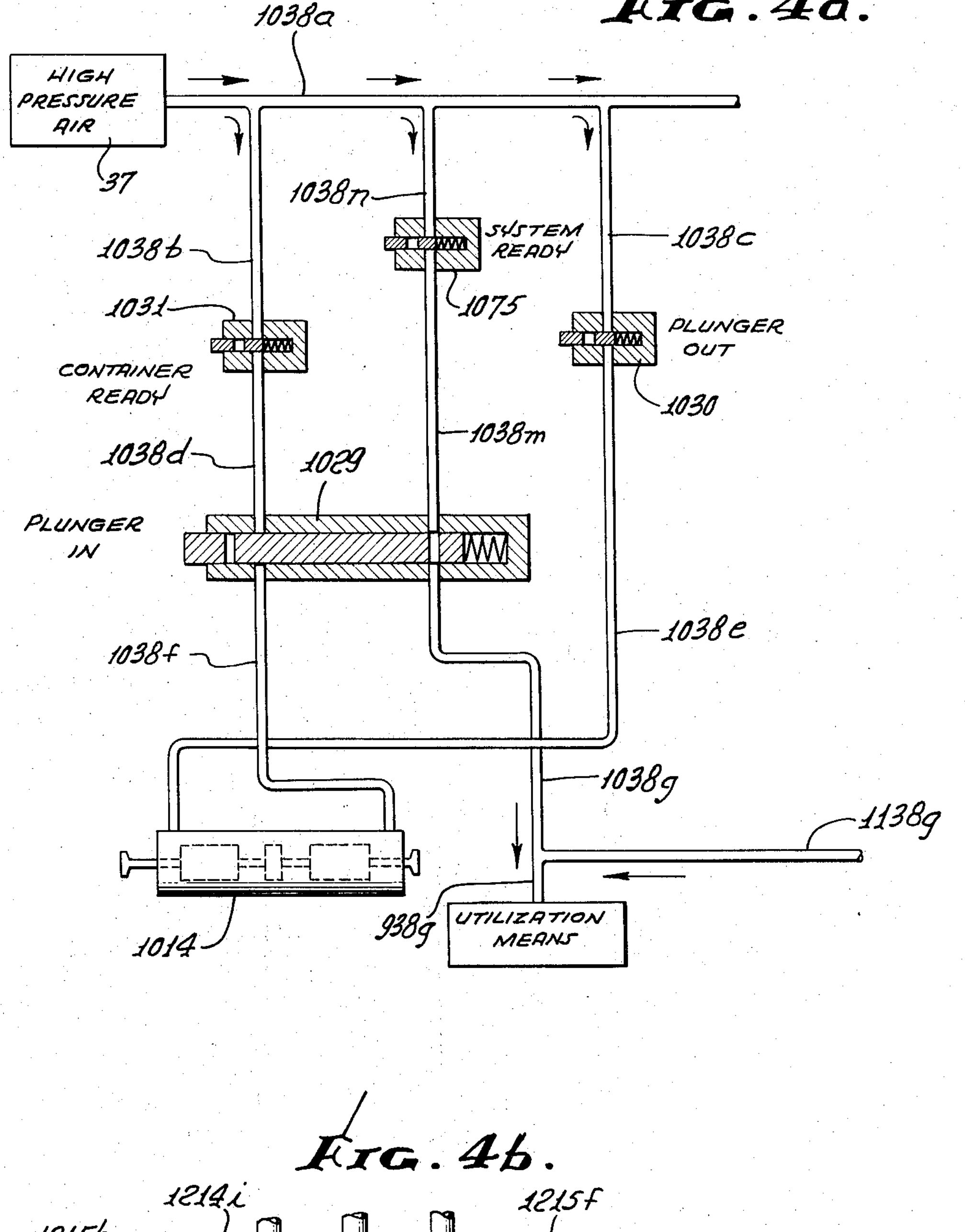

1038a
HIGH PRESSURE AIR
37
1038n
SYSTEM READY
1038b
1038c
1075
1031
PLUNGER OUT
CONTAINER READY
1030
1038m
1038d
1029
PLUNGER IN
1038e
1038f
1038g
1138g
938g
UTILIZATION MEANS
1014

FIG. 4b.

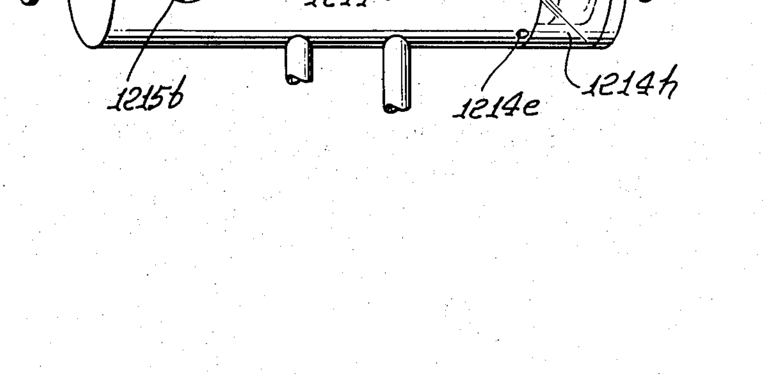
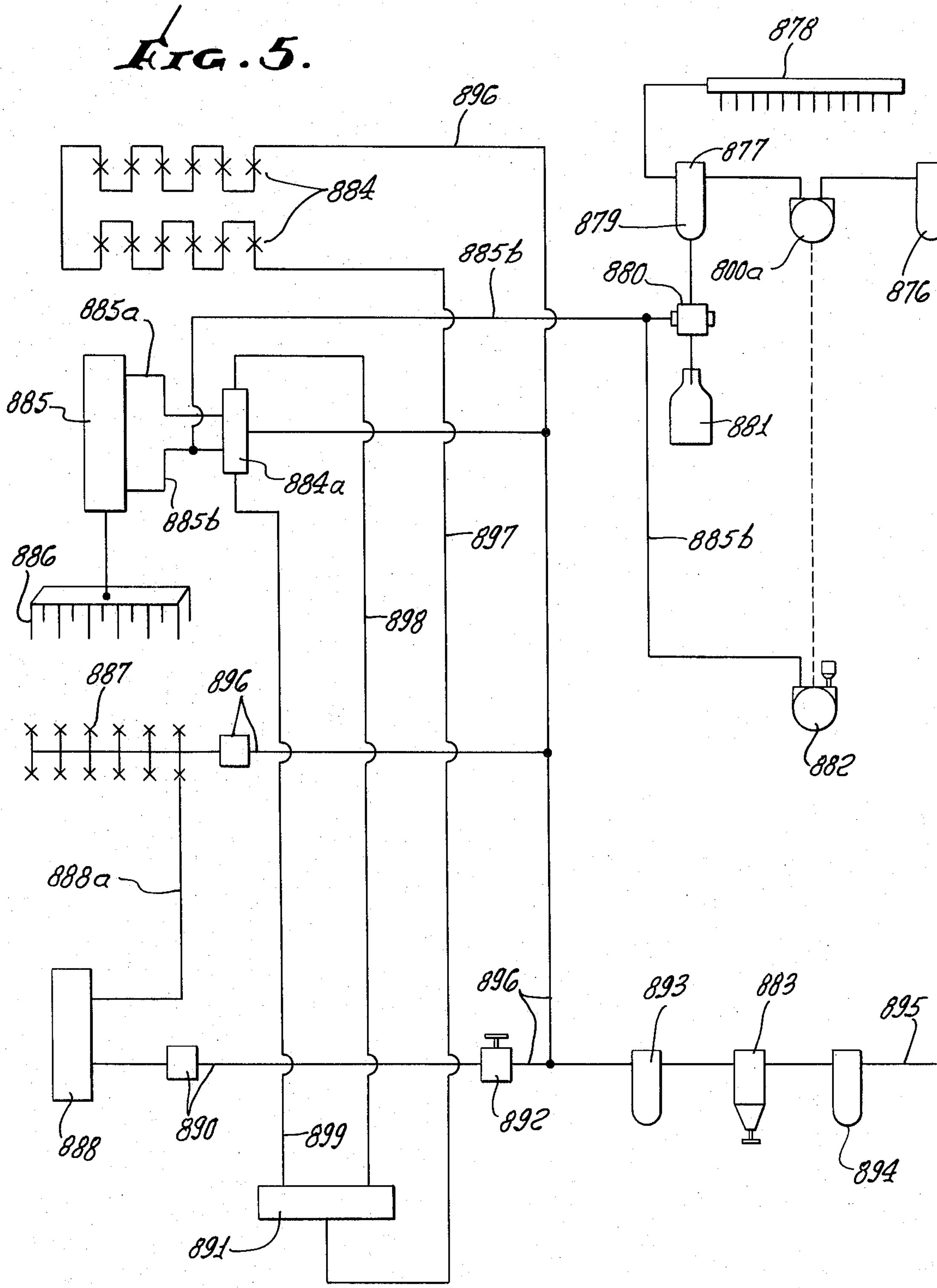

1214i
1215f
1215h
1215g
IN
~1214~
1215b
1214e
1214h

FIG. 5.


878
896
877
884
879
885b
880
800a
876
885a
885
881
884a
885b
897
885b
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898
887
896
882
888a
896
893
883
895
888
890
892
899
894
891

ANTIDRIP VOLUMETRIC RAPID FILLING MACHINE

SUMMARY OF THE INVENTION

This invention relates to the filling of containers, such as bottles, with flowable substances ranging from very viscous to very thin and including substances which readily form suds or foam.

Through advantageous combination and coordination of certain principles and features heretofore known and employed in distinct and disparate segments of the filling-machine art, and heretofore thought incompatible by many practitioners of this art, the instant invention makes possible a combination of high filling speed and remarkably fine volumetric precision and accuracy heretofore considered unfeasible.

The principles referred to are as follows:

(1) Accurate fill requires a cyclically operating volumetric metering device. (2) Accurate fill requires close control of liquid at all points in the system downstream from the metering device, to prevent loss of liquid to the surrounds or otherwise — so that all liquid metered actually enters and remains in the bottle, and no unmetered liquid enters the bottle.

(3) Accurate fill requires close control for and accounting of air which is or might be in the system, as such air affects the fill to the extent of the volume displaced. In some cases such trapped air may be gradually removed in successive fills; in other cases a bubble may remain trapped, expanding and contracting variably during the filling cycles; in either event objectionable imprecision of fill results. Leakage of the air into the system must be prevented, and air normally present in the system at startup, or injected into the system unavoidably as by the "whipping" action of some sorts of supply pumps and like devices, or by cavitation, must be systematically removed.

(4) Accurate fill requires close monitoring of system operation to guard against the possibility of bottles leaving the filler with only a partial fill due to incomplete cycling of the volumetric device.

(5) Accurate fill in a multiple-head filling machine requires that all the heads be operated under as nearly as possible identical conditions of flow rate as well as nominal volume setting. Otherwise small differences in pressure drop through the dispensing lines can cause slightly different behavior of the fluid at and leaving the dispensing nozzle, and at other places in the system, thus rendering the fill imprecise due to inter-head effects.

(6) Accurate fill requires that the operation generally be clean, in the sense that normal function of the filler should not deposit fluid on external surfaces of the bottle or the filling machine itself — even if these be quite reproducible or consistent in volume lost from the fill. Such external deposits even if reproducible have the effect of masking or concealing malfunctions of the apparatus — such as leaky seals in or downstream of the volumetric filler — and thereby prolonging the duration of such malfunctions until they become relatively more significant.

The implementation of these six principles in the present invention is described in general terms in the following paragraphs.

While these principles taken individually are recognized in various portions of the filling-machine art, as shown below their proper coordination and cooperation has never been effected, prior to the present invention.

In the present invention the volumetric device is a bi-acting piston operating in a cylindrical chamber. By "bi-acting piston" is meant a piston which meters fluid to the dispensing nozzle in both directions or strokes of its complete metering cycle.

Close liquid control in the present invention is obtained by (a) employing a submersible dispensing nozzle, which fills deep within the bottle so that sudsing or foaming of liquids subject to such tendency upon impact with the bottom of the bottle from a considerable height is minimized; and by (b) fitting the dispensing nozzle with a closure device which prevents uncontrolled discharge of fluid from the nozzle when the piston is not actually in motion, so that fluid intended for one bottle does not end up in the previous or next bottle; and by (c) further fitting the dispensing nozzle with a suitable mechanism for picking up drops of fluid from the tip of the nozzle as it is withdrawn from the bottle after filling, to avoid these drops dripping into the container and thereby changing the fill, and also to avoid their dripping onto the outside of the container or onto the filling machine itself.

Close control of air in the present invention is obtained in part by advantageous combination of some features already described — viz., (a) the use of a bi-acting piston to avoid sucking air into the volumetric chamber on the fluid-intake stroke, as happens with a single-acting piston; and (b) the use of a closable dispensing nozzle, which prevents uncontrolled admission of air to the system through the nozzle whilst preventing uncontrolled release of fluid. Air control is further effected by (c) interaction between the bi-acting piston and the closable nozzle, the latter permitting positive-pressurized operation of the entire system at all times, to avoid sucking air into the volumetric chamber or other portions of the system across auxiliary or secondary seals — such as, for example, at a seal between the volumetric chamber and a plunger attached to the piston and extending through an end wall of the chamber for purposes of providing an external indication of piston position, and at other seals such as gaskets, hose connections and the like; (d) suitable isolation of the fluid-transferring tubulations, ducts and chambers from the tubulations of any pneumatic control system — particularly if at high pressure — employed to monitor or direct system functions; (e) relative positioning of the dispensing nozzle above the volumetric chamber, so that air initially in the lines therebetween, and particularly within volumetric metering chambers, at startup tends to be eliminated promptly through its own buoyancy; (f) shaping and orientation of the piston and chamber so as to force any air bubbles out of the chamber promptly upon startup; and (g) provision of an entrapment device upstream of the volumetric chamber, to collect and remove any air initially present in the fluid supply or whipped into the fluid supply as by centrifugal pumps — or bubbles of air or fluid vapor produced by cavitation.

Close monitoring of system operation in the instant invention is effected by providing an extension of the piston through the volumetric chamber wall, and using the motion of this extension outside the chamber for monitoring and control of the system-function sequence. In particular (a) this extension, or "piston rod", or "plunger", is made to operate suitable sensors — e.g., mechanical, magnetic, pneumatic, electrical — to determine whether and when the piston completes its stroke before initiating a stroke in the opposite direction, and in particular whether and when the piston completes a full volumetric cycle, to give a full fill for an individual bottle, before initiating the next volumetric cycle; moreover (b) appropriate system functions are interlocked with the above-mentioned sensors to alert the human operator of such incomplete cycling, and/or to halt system operation at least for the affected head until corrective action can be taken manually to prevent an incompletely-filled bottle from leaving the filler in the production line, and/or automatically to effect such corrective action.

Operation of all heads under substantially identical conditions or nominal volume setting and flow rate is implemented by providing (a) individual volume adjustment for each head — this being conveniently effected, for example, by adjusting the distance between the sensors which detect, and thereby define, the arrival of the external end of the plunger at the extremes of its motion, because the volume dispensed is directly proportional to the "throw" of the piston at each stroke — and (b) individual flow-rate adjustment for each head — this being conveniently and stablely effected by providing in the apparatus a selectable plurality of constrictions or orifices of different size for insertion in the flow path to each dispensing nozzle — and (c) common volume adjustment for all units in a multiple-head filling machine — whereby the individual volumes once equalized can be all varied together over small excursions to obtain exactly the correct volume required (and whereby also, by operation of the common adjustment through larger excursions, the above advantages can be obtained with a single multiple-head filling machine for filling bottles of greatly different size, as for example 1 pint to 5 gallons).

Clean operation in the present invention is obtained by (a) provision of a suction-operative drop-catching mechanism at the nozzle, which is carefully synchronized with system suquencing so that it does not suck fluid up from the body of fluid in the bottle but only sucks drops — potentially drips — from the tip of the nozzle, well above the fluid level in the bottle, after filling; and (b) provision of interlocks preventing system sequencing, and/or actual discharge of fluid from the dispensing nozzle, in the event that no container is fed into receiving position under that particular nozzle. These provisions in turn interact with the positive pressurization mentioned above as important for air control, in that a leaking seal anywhere in the system will produce an external deposit which can be seen — since the bottles and system in normal, proper operation are clean — thereby flagging the existence of the leak even when it amounts to only one or two drops per bottle.

BACKGROUND OF THE INVENTION

While some of the above points taken individually and cursorily may seem apparent, and while the filling-machine art and industry has stood severely in need of a machine which is both extremely rapid and extremely accurate — since, in particular, the users of filling machines labor under considerable economic disadvantage from the unavailability of such machines — it nonetheless remains true that the above principles have never heretofore been cooperatively combined and coordinated in the ways and for the purposes herein described.

As a direct consequence the current state of the filling-machine art considers imprecisions of 1 or 1½ ounce per gallon — or 0.8 to 1.2% — to be at the limit of feasible operation, in a reasonably rapid filler. Since packaging companies must under the law fill every container with at least as much fluid as is nominally contained — i.e., as the label indicates — this means that the average container must be overfilled by at least 0.5 to 0.75 ounces per gallon, or 0.4 to 0.6%. Needless to say, 0.4% of the dollar value of product dispensed by a large manufacturer of liquid detergent, or antifreeze, or solvent, amounts to a significant sum — particularly in low-profit-margin industries, where 0.4% of the gross dollar value may represent 20% of the net profit.

Yet the requirement that every customer receive at least a nominal fill is properly founded in the currently maturing concern for consumer protection; while the objectionability of significant overfill, in some industries, is compounded by the undesirability of waste per se from an ecological or natural-resourcesconservation point of view.

By contrast the above-stated principles of the present invention, skillfully applied, permit manufacture of filling machines precise to 1/28 ounce, or roughly five drops, per gallon, or 0.03%. This precision is 30 times — well over an order of magnitude — finer than that obtainable with the best filling machines heretofore available.

Previous filling machines have employed submersible nozzles, some with closable tips. However these have been employed primarily with bottom-filling valves for sudsing liquids, in which the product is transported into the container without premeasuring, and such fillers are subject to considerable inaccuracy both through the absence of an accurate volumetric system per se and also through the fact that any drip-catching mechanisms associated with such fillers have operated to draw off fluid below the fluid level in the bottle, thereby variably (i.e., imprecisely) diminishing the fill.

Other previous filling machines have employed volumetric pistons, but most of these have objectionably been single-acting devices, wherein the piston is driven back and forth by a mechanical cam or like mechanism, only sucking product into the cylinder at one stroke and only driving it from the cylinder in the following stroke. I have found experimentally that tiny bubbles are entrained at the piston-chamber seal during the suction stroke, in such fillers, and on the expulsion stroke some of the bubbles are carried with the fluid to the dispensing nozzle, or as earlier noted remain trapped and are subject to variable expansion and contraction, in either event variably and objectionably diminishing the volume of fluid dispensed. Pat. Nos. 3,419,053 to Tanner; 2,276,157 and 2,303,822 to Chapman. A bi-acting piston is disclosed by E. A. Pontifex in U.S. Pat. No. 162,575. In the Unilever Patent Specification, the piston is a dual element having an air space between its two pressuring sides and thus failing to obviate the air-entrainment disadvantages of the single-acting piston. Moreover neither of these devices includes in cooperation with the volumetric piston a submersible, closable nozzle with drip-catching provision and the other features herein described which are so important.

In this regard it is important to emphasize that for the fullest realization of the advantages of the instant invention all of the aforementioned principles must be brought into action, through suitable implementations such as the features herein described. That is, as these principles are functionally combined in concert the resulting incremental capability, with the addition of each principle, becomes qualitatively different — where by qualitatively different we here mean an accuracy improvement by considerably better than an order of magnitude in a clean, very fast filling machine, resulting in the qualitatively different capability of accurately filling each and every container to at least its nominal volume and with negligible overfill.

Of course it is possible to omit some of these principles and suffer the loss of this qualitative difference in capability only under extraordinary conditions: for example, omission of suitable sequence-control provisions may not prevent manufacture of a filling machine which is extremely accurate — except in the event of certain kinds of system misfunction such as incomplete cycling of the volumetric piston or failure of the bottle-feed mechanism. Hence some of these features may be regarded as secondary, and their omission from a particular device shall not diminish the applicability to such device of those of the appended claims which do not recite such secondary features.

All of the principles and features and their concomitant advantages may be more fully understood through understanding of the embodiments hereinafter described in detail, with reference to the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIGS. 1*a*, 1*b* and 1*c* are drawings in section showing the configuration of the submersible closable nozzle and the relative positions of its parts at three different positions relative to a bottle to be filled — these corresponding to five different phases of the operational suquence.

FIGS. 2 and 2*a* through 2*e* are drawings mostly in section and partly in elevation showing the configuration of the various parts, and the interconnections of these parts, forming one embodiment of the present invention, specifically one in which pneumatic valves are employed as sensors and are employed to control system sequencing. These illustrations represent the operation of a "single-head" system, that is, a system having only one piston and one nozzle for filling one bottle at a time; these illustrations also represent one head of a multiple-head system, that is, a system having a multiplicity of pistons each with its respective nozzle and sharing a common supply and certain other common elements for filling a multiplicity of bottles concurrently or even simultaneously.

FIGS. 2*a* through 2*d*, in particular, represent equivalent arrangements for connection of one of the modules in FIG. 2 to the other components of the FIG. 2 system. Also, FIG. 2*e* in particular represents the interior of that same module, partly cut away as in FIG. 2, but in FIG. 2*e* a certain movable internal part of that module is shown in a different position than that in which it is shown in FIG. 2.

FIG. 3 is an elevation drawing, partly cut away, showing portions of a rotary multiple-head filling machine in accordance with the instant invention. While an actual device of this sort may have as many as a dozen or twenty or even more heads, for purposes of clarity only three heads are illustrated in FIG. 3. It may be noted in this connection that the vertical orientation of the metering pistons and chambers arises from space limitations in multiple-head filling machines. The embodiment of FIG. 3 is substantially in correspondence with that of FIGS. 2 and 2*a* except that the sequence-monitoring and -controlling sensors are electrical rather than pneumatic.

FIG. 3*a* is an electrical schematic representing the electrical wiring to the elements forming each "head", and its corresponding peripheral devices, of FIG. 3.

FIG. 4 is an elevation drawing showing portions of a rotary multiple-head filling machine in accordance with the instant invention. This embodiment is as to hardware very similar to that of FIG. 3, and accordingly only one and part of a second head are shown; it is different from the embodiment of FIG. 3 in that pneumatic rather than electrical sequence sensing and control are employed, as in FIG. 2; and also in that the sequence-control logic is somewhat different, as hereinafter described.

FIG. 4*a* is a pneumatic schematic, with some devices shown in section, representing pneumatic tubulation connections to the elements forming each head, and its corresponding peripheral devices, of FIG. 4.

FIG. 4*b* is an elevation drawing showing certain variations in the design of a directional-control fluid valve employed in the various embodiments.

FIG. 5 is a pneumatic schematic representing connections for sequence sensing and control of a rectangular-array multiple-head filling machine in accordance with the instant invention, and intended for substantially simultaneous filling of containers in a "case-at-a-time" or "in-line" ("line-at-a-time") mode.

DESCRIPTION OF EMBODIMENTS

As shown in FIGS. 1*a* through 1*c*, the submersible closable nozzle assembly comprises three basic parts:

(1) a subassembly 1 consisting of a supply body la and attached rotably thereinto a supply hood 1*b* with lateral orifices 1*k* and 1*j* and integrally attached center-pin 1*c* and tip 1*d*, and the supply body la also having a lateral supply tubulation 1*g;*

(2) a supply sleeve 2;

(3) a vacuum hood 3 with depending section 3*b*, downward-extending actuator step 3*a*, and lateral vacuum tubulation 3*c*.

There are in addition five O-ring (or T-ring) seals 7, 8, 9 and 10, and two springs 5 and 6. The entire assembly is suspended from a lowerable support staff 1*h* —indicated as a rod extending upwards out of the drawings — which is integral with the supply body 1*a*.

The apparatus is essentially a figure of revolution — i.e., cylindrical or conical — except for the lateral tubulations 1g and 3c, the lateral orifices 1*k* and 1*j*, the transverse passage 1*f* in the tip 1*d*, the "actuator" section 3*a* which forms part of the right side of the vacuum hood 3, and the springs 5 and 6.

Lateral dimensions are greatly exaggerated related to vertical dimensions, for the sake of clarity.

In FIG. 1*a* the apparatus appears suspended above a container 4, such as a bottle, which is to be automatically filled using the apparatus.

Note that in FIG. 1*a* the vacuum hood 3 and supply sleeve 2 are both in contact with the seals 9 and 10 mounted in the tip 1*d*. Thus the materal supply — generally liquid or syrup — is constrained within the cavity formed by the supply body **1***a*, supply hood **1***b*, and tip **1***d;* while the vacuum system sucks air from the vicinity of the bottom of tip **1***d*, via tubulation **3***c* and the passages **1***f* and le within the tip. As shown, neither spring is compressed beyond the amount required to effect good seal closures at seals **9** and **10.**

If FIG. **1***a* is taken to be a view of the nozzle assembly descending into position to start filling the bottle, then of course there is no liquid in the bottle; hence eventual liquid level **11***a* is shown here in phantom line. At this stage, the sucking operation through the vacuum hood is not accomplishing any useful purpose — but it is normally left in operation for simplicity of the control system.

As the assembly is lowered further, the actuator portion **3***a* of the vacuum hood **3** contacts the top of the bottle **4,** preventing further descent of the vacuum hood. The rest of the assembly continues to move down, compressing the springs — primarily the lighter spring **6.** The supply sleeve **2** slides through the seal **8** mounted inside the vacuum hood, so that the supply sleeve, the centerpin and the tip continue downward to the position shown in FIG. **1***b*. The lower seal **10** mounted on the tip **1***d* is now lowered out of contact with the vacuum hood **3,** so the vacuum system is now sucking air from the region above the tip. The supply sleeve **2,** however, is still maintaining contact with its tip seal **9,** so there is still no supply flow and no fluid in the bottle.

As the supply body and hood, centerpin and tip — subassembly **1** — continue to move downward, the lighter spring **6** is fully compressed, between the vacuum hood **3** and the flange **2***a* of the supply sleeve **2,** stopping descent of the supply sleeve. The supply body, hood, centerpin and tip, however, move still further — lowering the upper seal **9** on the tip out of contact with the supply sleeve **2** — to the position shown in FIG. **1***c*. This permits supply flow, and the bottle is filled. Filling is expedited — though under some typical conditions this effect is negligible — by removal of air from the bottle by the vacuum system; air is also pushed out of the mouth of the bottle by the rising fluid. At the lowest point of descent of the supply body, hood and attached centerpin and tip, the inside of the hood may contact the top of the supply sleeve — depending on equipment design. The fluid rises above the bottom of the supply sleeve, to the level **11**a shown in FIG. **1***c*.

When the rated fluid volume has been transferred to the bottle, the supply body and attached parts rise again. At the position of FIG. **1***b*, with the tip **1***d* and the bottom of the supply sleeve **2** still immersed, the supply channel is again closed. This prevents spillage of uncontrolled quantities of fluid from within the sleeve, between fills, either into a container or otherwise.

The assembly rises toward the position of FIG. **1***a*, where the vacuum system sucks fluid drops from the tip, providing a clean fill.

Flow-rate adjustment is implemented by providing a plurality of orifices such as **1***j* and **1***k* arrayed about the periphery of the upper portion of supply hood **1***b*, each selectably positionable for communication with supply tubulation **1***g* by means of rotation of hood **1***b* with respect to supply body **1***a*. Suitable detent means (not illustrated) are provided to maintain the hood **1***b* in the angular position thus selected.

The apparatus may take forms considerably different from that illustrated, but the key features are (1) provision for supplying material to fill the container via a conduit whose lower end extends into the container and is submerged by the fluid in the container when the fill is complete; (2) closing of the fill conduit before the nozzle is removed from the fluid; (3) provision for vacuum removal of drips, after the nozzle is removed from the fluid, and (4) flow-rate adjustment. A secondary feature is (5) vacuum assist of air removal from the container during filling.

All of these characteristics are directed to producing a rapid but extremely accurate and clean fill.

The systems shown in the following illustrations all include submersible filling nozzle assemblies per FIGS. **1***a* through **1***c*, though not shown in such detail.

FIG. **2** illustrates generally the subassembly **1,** sleeve **2,** vacuum hood **3** and attached parts, identified as in FIGS. **1***a* through **1***c*. The fluid level in FIG. **2** is shown in **11***b;* thus the sequence in FIG. **2** has proceeded to the point at which the nozzle is in the position of FIG. **1***c* but the liquid level has not yet risen to the level **11***a* therein indicated.

Raising and lowering of the nozzle subassembly relative to the container is in principle effectable either by raising the container or lowering the nozzle subassembly. Of these alternative and equivalent ways of operation only the latter is herein pictured. In FIG. **2** the subassembly is shown as controlled by air cylinder **35,** under control of bidirectional pushbutton valve **36;** supplying air from source **37** to cylinder **35** raises the subassembly, and interrupting the air connection permits the subassembly to descend under the influence of gravity. Valve **36** may be operated manually or pedally by forces at **36***a* and **36***b*, or may as appropriate be connected for actuation by mechanical cams or other means.

Vacuum connection via **3***c* is made to vacuum vessel **800,** whose internal volume is suitably maintained at a negative pressure relative to ambient by a pump mechanism whose final delivery chamber is representable as vessel **800.** Fixed to support staff **1**h is pushbutton valve **31,** for use as described below.

Shown generally at **26** is a volumetric chamber defined by end walls **26***a* and **26***g*, side wall **26***b*, and other seals and porting as apparent. A piston is shown within the chamber at **27,** with upper face **27**l and advantageously shaped with lower face **27***b* and a shaped projection **27***c* adapted for interaction with the corresponding features of wall **26***g* as herebelow detailed. The piston is also provided with extension **27***e* and remote actuating member **27***f*, and the piston and extension are mounted for longitudinal sliding motion within and outside of the chamber while maintaining seals thereto at **25** and **24** — thus forming subchambers for fluid at **11***i* above and **11***j* below the piston.

Also suitably mounted to chamber **26** as by brackets **28, 28***a* and **28***b* are pneumatic pushbutton valves **29** and **30,** the latter being a single-channel valve and the former a dual-channel valve or two single-channel valves ganged together, or any other suitable functional equivalent. These valves are both adjustably positioned in the path of actuator **27***f* to "sense" positioning thereof and thus of the piston **27** within the chamber; and in response to such sensing to generate, when suitably excited by attachment of pneumatic tubulations **38***d* and **38***c* from compressed-air source **37,** pneumatic signals to control system operation as herebelow described. Actuated surfaces **30***a* and **29***a* of the valves **30** and **29** respectively are spring-loaded outwards and actuated by force from member **27***f*.

Flow of substance to be dispensed is to and from the chamber **26** via tubulations **12***d* and **12***e* and five-port, four-way valve **14.** This valve in turn is connected via tubulation **12***f* and other intermediate devices as shown to supply tank **42,** and via tubulations **12***b*, **12***c* and **12***a* to the dispensing-nozzle supply subassembly **1.** Within valve **14** is movable spool **15,** having three sections **15***b*, **15***d* and **15***f* just slightly smaller in external diameter than the narrowest internal diameter of the main barrel of the valve, and slidably sealed thereto as by seals **17, 18, 19, 19***a*, **19***b*, **20, 21** and **22** for motion between two positions: one position as shown in FIG. **2** and the other position as shown in FIG. **2***e*.

The length of central spool section **15***d* must be such as to bridge seals **19** and **19***a* or seals **19** and **19***b*, to prevent improper bypassing during shifting of the spool.

When spool **15** is in the position illustrated in FIG. **2,** fluid at **11**n from the supply **11**s via the intermediate tubulations and devices shown passes into subchamber **11**m within the valve barrel formed by the end walls of spool sections **15***f* and **15***d* and the outer cylindrical wall of necked-down intermediate portion **15***e*, and from this subchamber flows as at **11***k* into the lower subchamber of chamber **26,** holding fluid **11***j*. This fluid forces piston **27** upward by pressure at the lower surfaces **27***b*, **27***c* and **27***d* of the piston, whose upper surface **27***a* forces fluid **11**i correspondingly upward and out as at **11***h* into valve subchamber **11***g* formed by the end walls of spool sections **15***b* and **15***d* and the outer cylindrical wall of necked-down intermediate portion **15***c*. From this subchamber the fluid proceeds as at **11***e* and **11***d* to the dispensing nozzle subassembly **1.** Once filling has begun, the CONTAINER READY cam **32** must be manually or automatically withdrawn from contact with button **31***a*, as will be seen shortly.

During this operation, fluid is discharged at **11**c into the bottle **4,** and the actuator **27***f* rises toward button **30***a*. When the actuator fully depresses the OUT valve button **30***a*, compressed air from line **38**c proceeds via line **38***f* and hole **14***a* in the side wall of the four-way valve into contact with the end wall of spool section **15***b*, and the air pressure thereon forces the spool to the position shown in FIG. **2***e*.

Connections are thereby reversed so that entering fluid **11**n flows via **11***h* to **11***i*, forcing piston **27** downward and thereby forcing fluid at **11***j* from below the piston outward as at **11***k*, whence it traverses the valve and exits at **11***f* to **11***d*, where as before it reaches and is dispensed through nozzle subassembly **1** and sleeve **2.**

This operation continues until the piston bottoms out. Although actuator **27***f* does fully depress button **29***a* of the IN valve **29,** no control action results therefrom yet, because due to withdrawal of cam **32** the valve **29** is not pneumatically excited via valve **31.**

The dispensing nozzle is then raised from the container as by force at surface **36***a* of valve **36,** to actuate air cylinder **35**; the full bottle is removed and an empty one positioned in its place. Surface **36***b* is depressed to deactivate the air cylinder **35** and permit lowering of the nozzle.

After the vacuum hood **3** has had ample time to descend into contact with the top of bottle **4,** the cam **32** is replaced in the location shown in the figure. If the placement of a bottle in receiving position as shown has not been accomplished, then the nozzle has proceeded past the height illustrated and the button **31** is not in position to be depressed by the cam **32,** so no cycle-control action results. The same is the case in the event the nozzle fails to descend fully to engage the bottle.

However, if the bottle is properly in place then repositioning of cam **32** as illustrated provides pneumatic signal from source **37** via **38***a*, **38***b* and **38***d* to excite pneumatic sensor valve **29.** As the latter has, per the normal operational cycle above described, already been actuated, pneumatic signals are applied therethrough and via line **38***e* to hole **14***b* at the right (as illustrated) end of valve **14,** to force the spool back to the position shown in FIG. **2.** This initiates another filling cycle as above described, provided that the spool responds properly.

If the spool does not move in response to the pneumatic signal from valve **29,** the cycle will not start. This can generally be the case — barring serious breakdown — only when the system has been shut down for a period of many hours, permitting the compliant seals **17,** 18, 19, 19*a*, **19***b*, **20, 21** and **22** to "cold-flow" into the pores of the spool sections **15***b*, **15***d* and **15***f*. Breaking the spool loose under these conditions may require a force ten times the normal operating force applied to shift the spool back and forth. To ascertain whether this has occurred, external extensions **15***a* and **15***g* are provided for the spool and these are slidably sealed at **16** and **23** to the internal circumferences of apertures in the end walls. When the system is to be turned on after being shut down for several days, the operator first manually depresses buttons **31***a* and **29***a*, or button **30***a* as appropriate, while visually or otherwise observing the extensions **15***a* and **15***g* to verify that the spool is not "frozen" in place. When this verification can be satisfactorily completed, the substance supply can be connected and operation begun. If the initial verification attempt is negative, the operator can tap on an end anvil **15***i* or **15***h* to free the spool, and then repeat the test; of course the "tap" can be a force automatically applied through a cam or otherwise.

In the event that the nozzle is raised out of contact with the bottle, thereby sealing sleeve **2** to tip **1***d*, before the piston has had time to bottom out, then when the next bottle is in position and the nozzle lowered to contact the bottle and with it valve **38***b*, even if the nozzle stops at the correct height to engage cam **32** and excite valve **29** no pneumatic signal will pass through line **38***e* to shift the spool — because the button **29***a* has not been depressed by actuator **27***f*. This is essential to avoid passage of the previous (underfilled) bottle into production line and marketing, and to avoid continued underfilling of the series of bottles to follow.

Under these circumstances the valve **29** instead generates an incomplete-cycle signal via line **38***g* to utilization means which may comprise (1) an alarm as represented by bell **39** and pneumatically-actuated clapper **38***h*, (2) pneumatically-actuated supply-fluid shutdown valve **33** with reset button **33***a*, (3) pneumatically-actuated compressed-air shutdown valve **34** with reset button **34***a* and a time-delay provision comprising constriction **38***i* and expansion chamber **38***k* to ensure supply shutdown prior to disabling of the pneumatic system, or (4) interlocks (not shown) to remove the incompletely filled bottle from the production line. Depending on the details of system operation these shutdown provisions may or may not be useful in a given system.

Some systems may be supplied with fluid for dispensing via tubulation **12***f* directly from supply **11***s* in tank **42**, by gravity. In other cases a pump **43** may be provided; in such cases, particularly in the event a centrifugal pump is employed which tends to whip air bubbles into certain kinds of fluids, an air-entrapment device as indicated at **41** is desirable. Container wall **41** defines a broadened flow path for fluid **11***o*, relative to the breadth of other portions of the flow path as at **11***r* and **11***n*, so that the velocity of fluid through container **41** is greatly diminished relative to that through tubulations elsewhere in the system, as **12***g* and **12***f*. The exact dimensions and length of the container must be worked out in terms of the flow rates and viscosities for which the system is designed, so that air bubbles entering with the fluid from the tubulation **12***g* have ample time to rise to the top of the container **41** of their own buoyancy before reaching the dome section **41***a*. Such bubbles thus accumulate in the dome section **41***a* forming an air space above the fluid level **11***p*. As the fluid level **11***p* falls by accumulaton of additional bubbles the float **40** falls also and with it the attached needle of needle valve **40***a*, whereby air is exhausted through the escape needle valve **40***a* to maintain the fluid level **11***p* above the bottom of the dome section **41***a* — or in any event above the top of the exit tubulation **12***f*.

Another air-entrainment control feature is the cooperative shaping of piston **27** lower surface **27***b* and the projection **27***c* and its lower surface **27***d* with chamber lower end wall **26***c*, port **26***d* and the bottom **26***h* of port **26***d*, so as to expel from the chamber any air bubbles initially trapped in the system at startup. This effect is obtained in the embodiment shown by causing the clearance between surface **27***b* and surface **26***c* to be slightly larger at the center of the chamber than at its periphery, and causing the clearance between surfaces **27***d* and **26***h* to be slightly larger at the right side, which opens into to tubulation, than at the left (blind) side. That is, the inclination of the conical surface **27***b* to the diameter of the chamber is slightly less than the inclination of the conical surface **26***c* thereto, and similarly with conical surfaces **27***c* and **26***d*, and inclined planar surfaces **27***d* and **26***h*. Thus the periphery of the piston bottoms out to the periphery of the chamber end wall but the inner portions of the piston do not bottom out, thus forming a wedge-shaped space which squeezes bubbles toward the central port and down into the port and out through tubulation **12***e*.

Yet another air-entrainment control feature is provided in the form of double seals **17** and **18** in series, and **21** and **22** in series, with respective relief holes **14***d* and **14***e* to ambient pressure, whereby seal leaks cannot result in pneumatic air leakage into fill fluid (or vice versa) but only to the ambient air and surrounds.

To align the system for operation, the bracket **28***b* is adjusted to bring button **29***a* into its just-fully-depressed state when the piston **27** is fully bottomed out in the chamber. The bracket **28***a* is then adjusted so that button **30***a* is just fully depressed when the piston is raised to a position which dispenses through tube **12***d* half the desired fill volume — making appropriate allowance for the volume of the plunger with the chamber. This adjustment may be expedited in a variety of ways, such as the use of graduations along member **28** or weighing the fluid dispensed into a container while the container is still in position under the nozzle. In any event small adjustments will generally be required after the system is in operation to obtain an exactly accurate fill.

Rotation of the supply hood **501***b* with respect to supply body **501***a* for the purpose of selecting orifices to regulate flow rate — and correspondingly for each of the other heads on the filler, all as described with respect to orifices **1***k* and **1***j* of FIGS. **1***a*, **1***b* and **1***c* — is particularly important in all multiple-head systems, including that illustrated in FIG. **3**, to equalize flow rates for the purposes set forth hereabove under Summary of the Invention.

Numerous other arrangements for connection of the valve **14** to chamber **26** and to supply tank **42** and nozzle subassembly **1** are equivalent in operation to that shown in FIG. **2**. Some of these equivalents are pictured in FIGS. **2***a* through **2***d*. While the type of valve pictured in FIGS. **2** and **2***a* through **2***d* is particularly well suited to use with a highly precise and rapid filling machine, other types of valving providing — as does this type — four flow paths, available in two combinations, are in principle equivalent and may be substituted as appropriate.

The hardware at each head of FIG. **3** is highly similar to that indicated in the system of FIG. **2**. One important difference is that the pneumatic sensors **29, 30** and **31** and the pneumatic spool-shifting provisions of FIG. **2** are here substituted for by electrical sensors **529, 530** and **531** and electrical solenoids **570** and **569**, for the head shown near the left-hand side of the figure; correspondingly numbered elements with the prefix "**6**" for the head shown near right-center, and correspondingly numbered elements with the prefix "**7**" for the head shown near the right side of the figure. Another difference is that the connections between the valves and supply nozzles have been shown somewhat more realistically in FIG. **3** as comprising flexible sections **512***h*, **712***h* to accommodate nozzle vertical motion. Another important difference is that the apparatus is here mounted and the bottles rest on a rotary platform **89**, and all of the other elements of the apparatus similarly rotate with platform **89**, through mechanical interconnections not illustrated — with the exception of tank **42**, hand-operated sprocket **53**, bell **390**, relay **56**, motor-gearbox **57–58** and electrical attachments thereto and gear **59** driven thereby, pump **800**, cams **43** and **66** and the various attachments thereto, all of which are stationary.

Wires to the various electrical components are connected as indicated schematically in FIG. **3***a*, to obtain substantially the same logical sequence-control functions as in FIG. **2**, but here electrically. While connections for only one head are shown in FIG. **3***a*, these connections are duplicated for each of the other heads of FIG. **3**. Connections from the rotating platform to the stationary elements of the apparatus are made via slip-contacts or "brushes" **931** for the "hot" power line, **969** for the ground line, and **929** for the utilization means, here comprising a bell **390**, and a relay **56** for interrupting power to drive motor **57** to stop rotation of the apparatus in event a CONTAINER READY switch is actuated before an IN switch. The CONTAINER READY switches here are actuated by cam

66, suspended by hinge 65 from stationary plate 62. If desired to avoid the possibility of multiply overfilling a container in the event the rotary platform should stop with one of the CONTAINER READY switches depressed by cam 66, solenoid 67 may be positioned by bracket 64 and operated in response to platform stoppage, by application of power via connections 63 to pull cam 66 out away from engagement position, and then by interruption of power via connections 63 to the solenoid to release the latter into engagement position subsequently when rotary motion resumes.

As shown in FIG. 3 the raising and lowering of the nozzles is effected by cam 43, shown partially cut away, which raises the nozzles by pushing on suitably mounted cam followers fixed to the support staffs of the nozzle subassemblies. Here the followers are shown as conveniently mounted just behind the switches, on the respective staffs.

As in FIG. 2 the switches 529, 530 and so forth are mounted for vertical adjustment, so as to permit alignment and volume calibration as earlier described. Here however there is an added important feature in the mounting of all the OUT switches to a common plate 44, suspended by threaded rods 45 from the upper rotating plate 60. The distance between platform 89 and plate 44 is controlled by adjusting the distance between plates 44 and 60, and this in turn by adjusting the angular positions of the threaded rods 45.

The threaded rods in turn are rotated by sprockets 46, in turn operated by chain or belt 61. The belt 61 is functionally connected by sprockets 49*a*, 49, and 51, and belts 50 and 52, to sprocket wheel 53 and handle 54, stationarily mounted for rotation about the axis of wheel 53 as at 55. By this means common adjustment of the volumes dispensed at all the heads may be effected by manipulation of the handle 54 whether the platform and the rest of the machine are rotating or not. When the machine is in operation and rotating, the handle 54 is continually turned by the action of belt 61 upon sprocket 49*a;* the handle may be momentarily manually stopped, or pushed forward momentarily in the same direction as its continual travel, to make a small adjustment in the height of plate 44 and thereby the volumes dispensed from all the heads in common.

Bottles are loaded onto the rotary platform 89 and unloaded therefrom near the right-hand end of the drawing, where as shown cam 43 causes the nozzles to be in raised position. The actuator as at 727*f* should in normal operation be fully down when the heads pass this point, and should be only just beginning to rise as at 627*f* for heads which have just passed cam 66. The system operation for heads in the position shown with prefixes "5" in the callouts, near the left-hand side of the drawing, corresponds generally to the phase of operation represented in FIG. 2.

Suction lines 503*c*, 703*c* and so forth are connected by a conventional rotary joint to suction line 803*c* from the pump 800.

The system of FIG. 4, like that of FIG. 2, employs pneumatic sensors and pneumatic actuation of the spool valve; it also employs pneumatic actuation via air cylinder 867 of cam 66. The elements of the head shown near the left side of FIG. 4 correspond to those in FIGS. 2 and 3 with the substitution of callout prefixes "10"; and the elements of the head shown near the right side of FIG. 4 correspond similarly with the substitution of callout prefixes "11".

Valve 1038*q* from the high-pressure air supply 37 to air cylinder 867 is operated to withdraw and release cam 66 in response to rotary-operation stoppage and resumption as described above for the solenoid operating cam 66 with reference to FIG. 3.

However the system shown in FIG. 4 is different in the details of its sequence-control logic, by the addition of pneumatic SYSTEM READY pushbutton valves 1075, 1175, and so forth, mounted for rotation with the upper plate. These valves are actuated by engagement with cam 76, stationarily mounted as by bracket 76*a*, to test the status of the IN pushbuttons while the nozzles are out of the bottles, in advance of the engagement of cam 66 with pushbutton valves 1131, 1031 and so forth. If as IN pushbutton such as 1029 is not properly depressed when the corresponding SYSTEM READY pushbutton 1075 is actuated by cam 76, pneumatic signals pass to utilization means 938*g* for alarm and/or shutdown functions as previously described. By providing this SYSTEM READY button-cam combination as a separate entity from the CONTAINER READY buttons and cam 66, some additional latitude is gained in the exact positioning of CONTAINER READY cam 66 angularly with respect to nozzle-raising cam 43 (FIG. 3). This can permit in some instances careful synchronization of the start of the piston cycle with respect to the opening of the nozzle; such careful synchronization is critical to avoid violent sudsing of some liquids on pressurized discharge from the nozzle.

FIG. 4*b* shows in one drawing various features which may be incorporated in the spool to provide external visibility of the position of the spool within the valve barrel. The external spool extensions as 1215*g*, shown in earlier drawings, are reproduced here for completeness. A section 1214*h* of the valve barrel may be constructed of transparent material to permit direct observation of the end 1215*f* of the spool. One of the isolation holes — represented as 14*d* in FIG. 2 — may be made large as at 1214*i* in FIG. 4*b* (with suitable separation of the isolation seals at the two sides thereof), exposing a portion of the spool wall 1215*b* and suitable indicia 1215*h* thereon. Again, these various features may be considered equivalent alternatives, any one of which may be employed, though some externally manipulable extension such as 1215*g* is in any event desirable to permit freeing of the spool by a manually applied blow or by automatic mechanical means.

FIG. 5 illustrates schematically the pneumatic connections for a case-at-a-time or in-line (line-at-a-time) filler. High-pressure air from a suitable compressor or other source enters the system at 895, and traverses filter 894, pressure regulator 883 and oiler 893 which provides lubrication for the various pneumatic valves and other pneumatically operated components. (These system elements 894, 883 and 893 may be present in the other pneumatic systems hereinabove discussed.) The 12 pushbutton valves 884 in series are IN sensors analogous in function to the lower section of valve 29 in FIG. 2, and the 2 pushbutton valves 887 connected in parallel to manifold 896 are OUT sensors analogous to the valve 30 in FIG. 2.

Spool valve 888 is typical of 12 such valves connected between manifold 890 and the respective pushbuttons 887, and is analogous in function to spool valve 14 of FIG. 2.

Nozzles **886** are representative of 12 nozzles identical in function to the nozzle assembly of FIGS. 1*a*, 1*b*, 1*c* and 2; these nozzles are raised and lowered in common by air cylinder **885,** in response respectively to pneumatic signals at **885***b* and **885***a* respectively, applied from selector valve **884***a* which is in turn controlled pneumatically by signals at **898** and **899** from foot-pedal-actuated selector valve **891.**

When pressurized air is applied through valve **884***a* to line **885***b* to raise the heads, this same line **885***b* also applies air to air motor **882** which operates vacuum pump **800***a*, fitted with muffler **876.** The vacuum pump applies suction via manifold **878** to the various suction lines as **3***c* in FIG. **2**, through separator bowl **879** which removes collected droplets from the suction path and deposits them via air-operated valve **880** in collector bottle **881.** The air-operated valve also receives controlling air signals via **885***b* when the heads are raised (or rising); to close valve **880** to obtain maximum suction; and to open valve **880** when the heads are lowered, to permit collected droplets to pass into bottle **881.** (System elements **882, 876, 879, 880** and **881** may advantageously be present in certain of the other pneumatic systems hereinabove discussed.)

To operate the system, with the heads initially all raised and the IN buttons **884** all depressed by their respective actuators (as **27***f* in FIG. **2**), and with a case of empty bottles in receiving position under the heads, the operator first operates pedal-actuated valve **891** to apply pneumatic signal from **896** via **884** and **897** to line **898,** which applies "pilot air" to shift the spool in valve **884,** applying high-volume air flow to air cylinder **885** via line **885***a* to lower the heads.

The operator then actuates start valve **892** to shift the spool in fluid-control valve **888,** and the other eleven valves of which it is typical, starting upward the volumetric pistons (not shown) operated by spool valves **888.** As soon as this happens the IN buttons **884** are closed by deactuation on the part of their respective actuators (such as **27***f* of FIG. **2**), preventing any further effect on the system of manipulating foot-pedal selector valve **891,** which may be released by the operator. If the latter valve is spring-loaded it will return to a position which effects continuity between lines **897** and **899,** but this has no observable effect on the system at this point in the sequence: during filling the air cylinder **885** is locked out of operation by the interruption of continuity at buttons **884,** so that the operator cannot erroneously initiate raising of the heads until the last one of the pistons has completed its cycle and restored continuity through buttons **884.** First, however, the several rising pistons actuate their respective OUT buttons, reversing the pistons at the tops of their respective strokes and continuing the filling cycles. When in fact the downward strokes are complete and continuity is restored through all buttons **884** the selector valve **891** can be reversed — or if spring-loaded has already been reversed by earlier release of the foot pedal — and the heads are raised together through application of air to cylinder **885** through **885***b*. The case of full bottles may then be removed, and a case of unfilled bottles placed in position for filling; the system is then ready to begin a new cycle of operation as above described.

I claim:

1. A system for filling containers with flowable substance from a source thereof, comprising:

- a volumetric metering chamber adapted to be connected to receive such substance from the source, and a bi-acting piston adapted for motion between predetermined limits within the chamber, for establishing controlled volumes of such substance;
- a submersible nozzle, connected to receive such controlled volumes of substance from the chamber, for discharge of such controlled volumes into such containers; and
- means for consistently removing drops of such substance from the nozzle tip after completion of each such discharge, without affecting the body of the substance in such container, comprising:
  - means defining a vessel;
  - means for establishing within the vessel a negative pressure with respect to ambient atmospheric pressure;
  - means providing physical communication between the interior of the vessel and the immediate vicinity of the nozzle tip; and
  - means for interrupting said communication during each such discharge, and after each such discharge while the nozzle tip contacts the body of the substance in such container;
- whereby drops of substance are sucked via the physical communication means and away from the immediate vicinity of the nozzle tip after each such discharge, but not until the nozzle tip is moved out of contact with the body of the substance.

2. A system for filling containers with flowable substance from a source thereof, comprising:

- a volumetric metering chamber adapted for connection to receive such substance from the source, and a bi-acting piston adapted for motion between predetermined limits within the chamber, for establishing controlled volumes of such substance;
- a nozzle, connected to receive such controlled volumes of substance from the chamber, and adapted for insertion into such containers, for discharge of such controlled volumes into such containers; and
- means, responsive to insertion of the nozzle into such a container in filling position at the nozzle, for inhibiting discharge of such metering-chamber-controlled volumes of such substance in the absence of a container in such position;
- whereby air within such container prior to filling is impelled outward by the rising upper surface of flowable substance injected into such container below the mouth thereof, but no flowable substance is discharged if no container is present in filling position.

3. A system for filling containers with flowable substance having low viscosity, and for filling containers with flowable substance having a tendency to form suds, from a source of such substance, comprising:

- a volumetric metering chamber adapted for connection to receive such substance from the source, and a bi-acting piston adapted for motion between predetermined limits within the chamber to meter a predetermined volume of substance out of the chamber through an exhaust port thereof; the chamber having a number of ports, said number including a plurality of ports each of which functions as an exhaust port of the chamber during operation of the system, each of said plurality of ports being at a respective elevation;

a dispensing nozzle for discharging such substance from a port of the chamber into each containers, said dispensing nozzle being at an elevation which is higher than the said elevation of each of the said plurality of ports;

means, connected to the chamber and to the nozzle, defining a flow path from a port of the chamber to the nozzle;

whereby bubbles in such substance within the chamber tend to escape, along the flow path, by buoyancy to and through the nozzle.

4. A system for filling containers with flowable substance from a source thereof, comprising:

a volumetric metering chamber adapted to be connected to receive such substance from the source and having an inner cylindrical surface terminating in at least one shaped end wall;

a port formed in the chamber at the same end of the chamber as the said wall;

a bia-acting metering piston positioned within the chamber, and adapted for motion therein toward and awy from said one end wall, to meter predetermined volumes of such substance out of the chamber via the port to such containers; and having an end surface facing said one end wall;

the end surface and end wall being so shaped as to expel from the chamber via the port any gas bubbles within the chamber, at the end of the exhaust stroke when the said end surface most closely approaches the end wall;

whereby metering accuracy is protected from degradation due to gas bubbles trapped within the chamber.

5. The system of claim **4**, wherein:

the end surface and end wall are both inclined relative to the diameter of the cylindrical chamber, the respective inclinations being slightly different so that at the end of the exhaust stroke when the end surface most closely approaches the end wall the space between surface and wall is thickest in a region adjacent the port;

whereby bubbles in the chamber tend to be squeezed out of the chamber via the port, at the end of the exhaust stroke.

6. The system of claim **5**, wherein:

the end surface and end wall are both substantially conical, the apex angle of the conical end wall being slightly smaller than the apex angle of the conical end surface; and

the port is formed substantially in the center of the end wall, whereby bubbles tend to be squeezed toward the center of the end wall and out through the port.

7. The system of claim **6**, wherein:

the end surface is formed with a projection closely fitted to the port, to further augment expulsion of bubbles therethrough.

8. A system for filling containers with flowable substance from a supply thereof, comprising:

a multiplicity of piston-chamber combinations, each having:

a bi-acting piston, and means defining a closely-fitted chamber adapted to be connected to receive such substance from the supply, and enclosing the piston slidably between controlled limits, for metering precisely controlled volumes of such substance from the supply thereof;

discharge means connected to receive such metered volumes of substance from the chamber and to discharge such volumes into such containers;

means defining an actuating surface movable with the piston;

limit means, fixed relative to the chamber and located and adapted to engage the actuating surface, for defining one end of the piston stroke; and

means, responsive to manual manipulation, for effecting relative longitudinal adjustment of the actuating surface and limit means;

whereby the overall volume of such substance metered by the piston and chamber from the supply into each container is adjustable by manipulation of the said adjustment-effecting means;

and all of said combinations operating concurrently to fill a multiplicity of containers concurrently; and

means for simultaneous adjustment, from a common control, of the relative positions of the entire multiplicity of actuating surfaces, each with respect to its respective limit means;

whereby the overall volume dispensed from each of the multiplicity of piston-chamber combinations is adjustable in common with that from each of the others of the multiplicity, even while the system is operating.

9. A system for filling containers with flowable substance from a supply thereof, comprising:

a multiplicity of piston-chamber-plunger combinations, each having:

a bi-acting piston, and means defining a closely-fitted chamber adapted to be connected to receive such substance from the supply, and enclosing the piston slidably between controlled limits, for metering precisely controlled volumes of such substance from the supply thereof;

discharge means connected to receive such metered volumes of substance from the chamber and to discharge such volumes into such containers;

a plunger attached to and movable with the piston, and extending longitudinally in a direction parallel to the longitudinal sliding motion thereof, through a compliantly-sealed aperture in the end wall of the chamber;

actuating means secured to the end of the plunger outside the chamber and remote from the end fixed to the piston;

limit means, fixed relative to the chamber and located and adapted to engage the actuating means, for defining one end of the piston stroke; and

means, responsive to manual manipulation, for effecting relative longitudinal adjustment of the actuating means and limit means;

whereby the overall volume of such substance metered by the piston and chamber from the supply into each container is adjustable by manipulation of the said adjustment-effecting means;

and all of said combinations operating concurrently to fill a multiplicity of containers concurrently; and

means for simultaneous adjustment, from a common control, of the relative positions of the entire multiplicity of actuating means, each with respect to its respective limit means;

whereby the overall volume dispensed from each of the multiplicity of piston-chamber-plunger combinations is adjustable in common with the from each of the others of the multiplicity, even while the system is operating.

10. The system of claim **9**, wherein the simultaneous adjustment means comprise:

means for mounting the entire multiplicity of chambers for mutually accurately parallel motion of all the pistons and plungers; and

means for mounting the entire multiplicity of limit means individually to a common plate, the said plate being mounted adjustably for motion accurately parallel to the said mutual parallel motion, thereby providing adjustment of the said one end of each piston's stroke by accurately equal increments from a single common control.

11. A system for filling containers with flowable substance, from a supply of such substance, comprising:

a submersible nozzle adapted for insertion into such containers and having a closure device at its tip to prevent uncontrolled discharge of substance therefrom;

means defining a chamber having a longitudinal direction, and connected to receive such substance from such supply, and connected to dispense such substance to the nozzle;

a bi-acting piston enclosed within the chamber for closely-fitted longitudinal sliding motion therein, for metering precisely controlled volumes of such substance from such supply through the submersible nozzle into such containers;

control-system means responsive to the piston, and comprising at least one piston-responsive member which is secured relative to the chamber, for reversing motion of the piston at each end of its stroke;

actuating-surface defining means which move with the piston longitudinally;

solid positive-stop means, longitudinally fixed relative to the chamber, and located and adapted to engage the actuating-surface defining means to positively halt the piston at each end of its stroke; and

means for adjusting the distance which the piston may move longitudinally relative to the cylinder, between the two points at which the control-system means respond to the piston, and between the two points at which the actuating-surface defining means engage the solid positive-stop means;

whereby the amplitude of piston excursion is positively but adjustably defined, and thus the metered volumes of such substances are substantially free of variation due to any time delay in operation of the control-system means.

12. A system for filling containers with flowable substance, comprising:

a supply of such substance;

a plurality of volumetric metering chambers, each having a corresponding bi-acting piston adapted for motion within that chamber and between predetermined limits, for establishing individually controlled volumes of such substance;

plural dispensing means for discharging such substance into such containers;

means connected to the supply, the chambers and the dispensing means, and defining a corresponding plurality of flow paths from the supply to the dispensing means via the chambers and pistons; and

means disposed along the flow paths for individually adjusting the discharge flow rates of such substance;

whereby the flow rates to the respective containers may be equalized.

13. The system of claim **12** wherein the rate-adjusting means comprise, for each of at least all but one of the said plurality of flow paths, respectively:

means defining a plurality of orifices of different sizes and adapted for passage of such flowable substance;

adjustment means for selectably positioning any of the orifices along the flow path, for passage of such substance therethrough.

14. A system for filling containers with flowable substance from a supply thereof, comprising:

a volumetric metering chamber and a bi-acting piston, adapted for motion between predetermined limits within the chamber, for establishing controlled volumes of such substance;

discharge means for dispensing such substance into such containers;

a multiple-port valve connected to ports at the two ends of the chamber and to the discharge means; and adapted to be connected to the supply; and having enclosed a spool which when cycling properly is driven between two positions in response to completion of motion by the piston in its two directions respectively; and which functions when in one of the two positions to direct such substance from the supply into a first port at one end of the chamber, and to direct such substance from a second port at the other end of the chamber to the discharge means; and which functions when in the other of the two positions to direct such substance from the supply into the said second port and from the said first port to the discharge means;

the sliding motion of the spool within the valve being subject to objectionable static friction interfering with proper cycling; and

means for indicating to a human operator when the spool moves from one of its positions to the other, whereby proper cycling may be verified.

15. A system for filling containers with flowable substance, comprising:

supply means for storing a supply of such substance;

volumetric metering means for conducting precisely controlled volumes of such substance from the supply means, the metering means being sealed against entry of air from containers being filled;

dispensing means, having a submersible portion defining a dispensing orifice, for conducting the volumes of substance from the metering means into such containers;

positioning means, attached to the dispensing means, for moving the submersible portion into dispensing position within such container; and

control means, also attached to the dispensing means, for sealing the dispensing orifice at its tip when the submersible portion is not in dispensing position;

whereby the dispensing orifice if opened at its tip to communicate the supply means with such containers via the metering means only when the submersible portion is in dispensing position, thereby avoiding uncontrolled release of such substance from the dispensing orifice.

16. The system of claim **15,** wherein:

the control means are responsive to physical engagement of a portion of the system with such container.

17. The system of claim **15** wherein:

the control means prevents admission of air into the system via the dispensing orifice.

18. A system for filling containers with flowable substance, comprising:

supply means for storing a supply of such substance;

volumetric metering means for conducting precisely controlled volumes of such substance from the supply means;

dispensing means, having a submersible portion defining a dispensing orifice, for conducting the volumes of substance from the metering means into such containers;

positioning means, attached to the dispensing means, for moving the submersible portion into dispensing position within such containers;

control means, also attached to the dispensing means, for sealing the dispensing orifice at its tip when the submersible portion is not in dispensing position;

whereby the dispensing orifice is opened at its tip to communicate the supply means with such containers via the metering means only when the submersible portion is in dispensing position, thereby avoiding uncontrolled release of such substances from the dispensing orifice;

vacuum means, comprising a vacuum vessel, for developing and maintaining a negative pressure differential, with respect to atmospheric pressure, within the vacuum vessel;

suction means, defining conduits connected with the vessel and with the dispensing means, and defining a drip-catching second orifice, for providing sealed physical communication between the vessel and the vicinity of the submersible portion of the dispensing means;

secondary control means, operable upon the suction means, for interrupting sealed physical communication between the second orifice and the vacuum vessel via the conduits, when the submersible portion of the dispensing means is in or nearly in dispensing position; and for restoring sealed physical communication between the second orifice and the vacuum vessel when the submersible portion of the dispensing means is not in or nearly in dispensing position;

whereby the second orifice provides suction at the submersible portion of the dispensing means, but only above the instantaneous level of substance within the container, for removing drips subsequent to filling.

19. The system of claim **18,** wherein:

the suction means also define a third orifice communicating between the conduits and the ambient air; and

the secondary control means comprise means for sealing the third orifice when the submersible portion of the dispensing means is not in or nearly in dispensing position; and for unsealing the third orifice, to substantially remove suction at the submersible portion of the dispensing means, when the submersible portion is in or nearly in dispensing position.

20. The system of claim **19,** wherein:

the third orifice is disposed near the position of the container mouth during filling;

whereby the third orifice provides suction at the mouth of the container, but always above the substance level in the container, for assistance in air removal from the container and for catching spray, during filling.

21. A system for filling containers with flowable substance, comprising:

supply means for storing a supply of such substance;

volumetric metering means, for conducting precisely controlled volumes of such substance from the supply means, comprising:

means defining a cylindrical chamber and defining a plurality of ports therein, at least one port at each end of the chamber;

a piston closely and slidably fitted within the chamber;

compliant means for effecting a sliding seal between the outer circumference of the piston and the inner surface of the chamber, whereby the piston forms a movable wall cooperating with the first mentioned defining means to define first and second subchambers, each having at lest one port;

a multiport spool valve connected to the two said ports in the chamber, and also connected to receive such substance from the supply means, and also connected to discharge such substance to the dispensing means recited hereunder, all as follows:

during a first half-cycle of operation, providing physical communication between the first subchamber and the supply means, whereby pressurized substance from the supply means forcibly moves the cylinder, enlarging the first subchamber and reducing the second subchamber, filling the first subchamber with such substance; and providing physical communication between the second subchamber and the dispensing means, whereby reduction of the second subchamber forcibly moves such substance out of the second subchamber to the dispensing means; and

during a second half-cycle of operation, reversing the physical communication connections and thereby the functions of the two subchambers; whereby in each full cycle of operation the dispensing means receive a controlled volume of substance equal to twice the volume swept through by the piston in one stroke;

dispensing means, having a submersible portion defining a dispensing orifice, for conducting the volumes of substance from the metering means into such containers;

positioning means, attached to the dispensing means, for moving the submersible portion into dispensing position within such containers; and

control means, also attached to the dispensing means, for sealing the dispensing orifice at its tip when the submersible portion is not in dispensing position;

whereby the dispensing orifice is opened at its tip to communicate the supply means with such containers via the metering means only when the submersible portion is in dispensing position, thereby avoiding uncontrolled release of such substances from the dispensing orifice.

22. In a system for filling containers with flowable substance from a supply thereof, a filling nozzle comprising:

means defining a support for such containers to be filled;

a supply body having:

a depending hood provided with seals for sliding relative motion of a tubing section in a constantly sealed relation therewith;

a depending tip-support structure and at the remote lower end thereof an integrally attached formed tip, the tip being provided with at least one tip seal for sealing engagement of at least one tubing section through relative longitudinal motion therewith, and

an internal passageway, adapted for connection to the supply, for flow of such substance into the hood from the supply;

means for effecting vertical relative motion between the support-defining means and the supply body;

a supply sleeve comprising a tubing section mounted for longitudinal sliding relative motion in a constantly sealed relation with the hood and adapted for longitudinal compressive sealing engagement with the tip, and adapted to provide conduction of substance from the body to the vicinity of the tip;

first compliant means limiting longitudinal motion of the supply sleeve toward the body hood; and

means, connected with the supply sleeve, and adapted for and responsive to engagement with such container to be filled, for urging the supply sleeve toward the body hood, acting against the compliance of the said first compliant means, only when the bottom of the supply sleeve is inserted into such container to be filled;

whereby longitudinal separation of the supply sleeve from sealing relation with the tip, to permit flow of substance from the supply via the sleeve into such container only when the bottom of the supply sleeve is inserted below the mouth of a container to be filled, is controlled by transmission of compressive force to the supply sleeve by the said urging means, from a container to be filled, as the supply body and the support are moved closer together by the relative-motion-effecting means; and

whereby air within such container before filling is impelled outward by the rising upper surface of flowable substance injected into such container below the mouth thereof.

23. In the system of claim **22,** the filling nozzle as therein claimed in an antidrip embodiment additionally comprising:

a vacuum hood comprising a tubing section mounted for longitudinal sliding relative motion about the centerpin and supply sleeve, and for longitudinal compressive engagement with the tip, and adapted to provide communication between a point above at least one of said tip seals and a partially evacuated chamber;

the said tip also having formed within it a suction conduit from the vicinity of the lower extremity of the tip to a point above at least one of said tip seals, for sucking substance droplets from the lower extremity of the tip into the vacuum hood and toward the partially evacuated chamber; and

second compliant means limiting longitudinal relative insertion of the supply sleeve into the vacuum hood and

the said supply-sleeve-urging means comprising means, connected with the vacuum hood, and adapted for and responsive to engagement with such container to be filled, for urging the vacuum hood toward greater relative insertion of the supply sleeve thereinto, acting against the compliance of the said second compliant means and thereby also urging the supply sleeve toward the body hood, only when the bottom of the supply sleeve is inserted into such container to be filled;

whereby longitudinal separation of the vacuum hood from sealing relation with the tip, to interrupt sucking of substance droplets from the vicinity of the lower extremity of the tip via said conduit toward the partially evacuated chamber when the bottom of the supply sleeve is within a container to be filled, is controlled by transmission of compressive force upon the vacuum hood via the said vacuum-hood-urging means from a container to be filled, as the supply body and the support are moved closer together by the relative-motion-effecting means; and

whereby the said sucking of substance from the vicinity of the lower extremity of the tip is interrupted during said flow of substance from the supply via the sleeve into such container.

24. A system for filling containers with flowable substance from a supply thereof, comprising:

a bi-acting piston, and means defining a closely-fitted chamber enclosing the piston slidably for motion of the piston between controlled limits, for metering precisely-controlled volumes of such substance conducted via supply tubulations into the chamber from the supply;

dispensing means, connected to receive said volumes of substance from the chamber, for discharging said volumes into such containers; and

means for removing air from the supply tubulations, comprising:

means forming a section of the supply tubulations and defining a flow path, for such substance, whose cross-sectional area and length in relation to the velocity and viscosity of substance conducted therethrough are sufficiently large to permit rising of air bubbles within such moving substance from the bottom to the top of the said flow path during the time such substance traverses the length of the flow path;

means defining an air-entrapment dome and an inlet thereto disposed for communication with the top of the said flow path and toward the downstream end of the said length thereof; and

release means, responsive to the quantity of air accumulated within the dome, for discharging air from the dome to maintain the substance level therein above the top of the flow path;

whereby the precise control of said volumes discharged into such containers is protected from degradation which would otherwise result from discharge of entrained air with such substance.

25. The system of claim 24, also comprising:
a four-way, five-port valve for effecting bidirectional fluid flow to and from the metering piston and chamber;
pneumatic control mechanisms for effecting reversal of the valve, and therefore the piston;
means defining an orifice and dispensing passageways for conducting the volumes of such substance from the piston and chamber into such containers;
first pressurization means for pressurizing the supply of substance so as to provide such substance to the flow path, tubulations, piston, chamber, passageways, orifice and valve at a first positive pressure relative to ambient atmospheric;
second pressurization means for pressurizing air so as to provide air to the pneumatic controls at a second positive pressure relative to ambient atmospheric, the second pressure being higher than the first;
pneumatic conduits and cavities providing physical communication between the pneumatic controls and the second pressurization means; and
isolating means for preventing transfer of air from the conduits, cavities and controls into the tubulations, flow path, chamber, passageways and valve, the said isolating means comprising:
dual sealing means intermediate between (1) on the one hand, each of the chamber, passageway and valve; and (2) on the other hand, each pressurized pneumatic conduit, cavity and control device; the dual sealing means comprising in series:
a first compliant seal exposed on one functional side to the substance at said first pressure and exposed on a second functional side to ambient air at atmospheric pressure; and
a second compliant seal exposed on one functional side to ambient air at atmospheric pressure and on a second functional side to the pressurized air at said second pressure;
whereby partial failure of such first seal produces pressurized leakage of such substance to ambient, and partial failure of such second seal produces pressurized leakage of compressed air to ambient; but in no case can second compliant seal failure produce leakage of compressed air into the tubulations, chamber, passageways and valve containing the substance; and in no case can first compliant seal failure produce leakage of the substance into the conduit, cavity and control devices containing the compressed air.

26. A system for filling containers with flowable substance from a supply of such substance, comprising:
a bi-acting piston, and means defining a closely-fitted chamber enclosing the piston slidably between controlled limits, for metering precisely controlled volumes of such substance from the supply;
means defining an actuating surface movable with the piston in an "in" direction and in an "out" direction relative to the chamber;
a plurality of sensing means disposed for actuation by the actuating surface, so as to sense the progress of the piston to and from its respective operating limits, and thereby when suitably excited to generate functional signals of such progress, the said plurality of sensing means comprising IN sensing means disposed to sense positioning of the piston at a first one of its two operating limits; and in addition
SYSTEM READY sensing means disposed to sense a ready condition of the system with respect to filling a particular container;
a valve, having a plurality of ports, adapted to be connected to receive such substance from the supply and also connected to deliver such substance to the metering piston and chamber, and further adapted and connected to effect bidirectionality of fluid flow to and from the metering piston and chamber; the said valve having a spool with a plurality of necked-down portions formed therein, and the said spool being driven, in response to the said functional signals, between two alternative positions corresponding to and inducing the two alternative directions of fluid flow to and from the metering piston and chamber;
dispensing means comprising:
means defining an orifice and a dispensing passageway, connected with the said valve, for conducting the volume of substance from the piston and chamber via the valve into such containers; and
orifice-control means, responsive to engagement of a component of the dispensing means with such container, for effecting discharge of such substance only in the presence of a container and for preventing admission of air via said orifice into the passageway; and
first functional-signal interconnection means between sensing means and spool valve, adapted to drive the valve-spool its position which initiates actuating-surface motion away from the IN sensing means only when the IN and SYSTEM READY sensing means are initially simultaneously actuated; whereby initiation of each half-cycle of operation away from the IN sensing means is contingent upon completion of the previous half-cycle of operation toward the IN sensing means; and
second functional-signal interconnection means between the sensing means and a signal-utilization means, for actuation of the signal-utilization means if the SYSTEM READY sensing means are actuated but the IN sensing means are not actuated; whereby further system operation may be made contingent upon response to the signal-utilization means.

27. A system for filling containers with flowable substance from a supply of such substance, comprising:
a bi-acting piston, and means deining a closely-fitted chamber enclosing the piston slidably between controlled limits, for metering precisely controlled volumes of such substance from the supply; and in conjunction:
a plunger attached to and movable with the piston, and extending longitudinally in a direction parallel to the longitudinal sliding motion of the piston relative to its chamber, through an aperture formed in an end wall of the chamber, the aperture being provided with compliant seal means to permit sliding motion of the plunger therethrough in an in direction and in an out direction while maintaining pressurization of the chamber;
actuating means secured to the end of the plunger outside the chamber and remote from the end fixed to the piston;
a plurality of sensing means disposed for actuation by the actuating means, so as to sense the progress of the plunger to and from its respective operating

limits, and thereby when suitably excited to generate functional signals of such progress; the said plurality of sensing means comprising IN sensing means disposed to sense positioning of the plunger at a first one of its two operating limits; and in addition

SYSTEM READY sensing means disposed to sense a ready condition of the system with respect to filling a particular container;

a valve, having a plurality of ports, adapted to be connected to receive such substance from the supply and also connected to deliver such substance to the metering piston and chamber, and further adapted and connected to effect bidirectionality of fluid flow to and from the metering piston and chamber; the said valve having a spool with a plurality of necked-down portions formed therein, and the said spool being driven, in response to the said functional signals, between two alternative positions corresponding to and inducing the two alternative directions of fluid flow to and from the metering piston and chamber;

dispensing means comprising:

means defining an orifice and a dispensing passageway, connected with the said valve, for conducting the volume of substance from the piston and chamber via the valve into such containers; and

orifice-control means, responsive to engagement of a component of the dispensing means with such container, for effecting discharge of such substance only in the presence of a container and for preventing admission of air via said orifice into the passageway; and

first functional-signal interconnection means between sensing means and spool valve, adapted to drive the valve-spool to its position which initiates plunger motion away from the IN sensing means only when the IN and SYSTEM READY sensing means are initially simultaneously actuated; whereby initiation of each half-cycle of operation away from the IN sensing means is contingent upon completion of the previous half-cycle of operation toward the IN sensing means; and

second functional-signal interconnection means between the sensing means and a signal-utilization means, for actuation of the signal-utilization means if the SYSTEM READY sensing means are actuated but the IN sensing means are not actuated; whereby further system operation may be made contingent upon response to the signal-utilization means.

28. The system of claim **27**, wherein:

the utilization means comprise an alarm for alerting a human operator when the SYSTEM READY sensing means is actuated but the IN sensing means is not actuated.

29. The system of claim **27**, wherein:

the utilization means comprise shutdown apparatus for interrupting feed of containers to and from the system.

30. The system of claim **27**, wherein:

the utilization means comprise shutdown apparatus for interrupting flow of substance from the supply.

31. The system of claim **27**, wherein:

the sensing means are pneumatic devices; they are pneumatically excited, the spool pneumatically driven and the utilization means pneumatically actuated.

32. The system of claim **31**, wherein:

the utilization means comprise shutdown apparatus for depressurizing the pneumatic control system.

33. The system of claim **27**, wherein:

the sensing means are electrical devices; they are electrically excited, the spool electrically driven and the utilization means electrically actuated.

34. The system of claim **27**, wherein:

the said plurality of sensing means comprises, in addition, OUT sensing means disposed to sense positioning of the plunger at a second one of its two operating limits; and

the first interconnection means are further adapted to drive the valve spool toward that position which initiates plunger motion toward the IN sensing means only if the OUT sensing means are actuated;

whereby initiation of each half-cycle of operation is contingent upon completion of the previous half-cycle.

35. The system of claim **34**, also comprising an additional multiplicity of such piston-chamber-plunger-actuating-means combinations, each provided with respective sensing means, and operating concurrently to fill a multiplicity of containers concurrently, and wherein:

operation of the system is characterizd by rotary motion of the said multiplicity of chambers about a common axis, and corresponding rotation therewith of containers to be filled; and

the utilization means comprise shutdown apparatus for interrupting said rotary motion.

36. A system for filling containers with flowable substance from a supply thereof, comprising:

a bi-acting piston, and means defining a closely-fitted chamber enclosing the piston slidably between controlled limits, for metering precisely controlled volumes of such substance from the supply; and in conjunction:

means defining an actuating surface movable with the piston in an in direction and in an out direction relative to the chamber;

a plurality of sensing means disposed for actuation by the actuating surface, so as to sense the progress of the piston to and from its respective operating limits, and thereby when suitably excited to generate functional signals of such progress, the said plurality of sensing means comprising IN sensing means disposed to sense positioning of the piston at a first one of its two operating limits; and OUT sensing means disposed to sense positioning of the piston at the other of its two operating limits; and in addition

CONTAINER READY sensing means disposed to sense presence of a container in ready position for filling with respect to the system;

SYSTEM READY sensing means disposed to sense a ready condition of the system with respect to filling a particular container;

a valve, having a plurality of ports, adapted to be connected between the supply and the said chamber, and between said chamber and dispensing means recited hereinbelow; and adapted and connected to effect bidirectionality of fluid flow to and from the metering piston and chamber; the said valve having a spool with a plurality of necked-down portions formed therein, and the said spool being driven, in response to the said functional signals, between two alternative positions corresponding to and inducing the two alternative directions of fluid flow to and from the metering piston and chamber;

dispensing means comprising:

means defining an orifice and a dispensing passageway connected with said valve for conducting the volumes of substance from the piston and chamber via said valve into such containers; and

orifice-control means, responsive to engagement of a component of the dispensing means with such container, for effecting discharge of such substance only in the presence of a container and for preventing admission of air via said orifice into the passageway; and

first functional-signal interconnection means between sensing means and spool valve, adapted to drive the valve spool to its position which initiates actuating-surface motion toward the OUT sensing means only when the IN sensing means and CONTAINER READY sensing means are initially simultaneously actuated; and to drive the valve spool toward that position which initiates actuating-surface motion toward the IN sensing means only if the OUT sensing means are actuated; whereby initiation of the first half-cycle of operation is contingent upon presence of a container, and initiation of the second half-cycle is contingent upon completion of the first half-cycle; and

second functional-signal interconnection means between the sensing means and a signal utilization means, for actuation of the utilization means if the SYSTEM READY sensing means are actuated but the IN sensing means are not actuated; whereby further system operation may be made contingent upon response to the signal-utilization means.

37. A system for filling containers with flowable substance from a supply thereof, comprising:

a bi-acting piston, and means defining a closely-fitted chamber enclosing the piston slidably between controlled limits, for metering precisely controlled volumes of such substance from the supply; and in conjunction:

a plunger attached to and movable with the piston, extending longitudinally in a direction parallel to the longitudinal sliding motion of the piston relative to its chamber, through an aperture formed in an end wall of the chamber, the aperture being provided with compliant seal means to permit sliding motion of the plunger therethrough in an in direction and in an out direction while maintaining pressurization of the chamber;

actuating means secured to the end of the plunger outside the chamber and remote from the end fixed to the piston;

a plurality of sensing means disposed for actuation by the actuating means, so as to sense the progress of the plunger to and from its respective operating limits, and thereby when suitably excited to generate functional signals of such progress; the said plurality of sensing means comprising IN sensing means disposed to sense positioning of the plunger at a first one of its two operating limits; and OUT sensing means disposed to sense positioning of the plunger at the other of its two operating limits; and in addition

CONTAINER READY sensing means disposed to sense presence of a container in ready position for filling with respect to the system;

SYSTEM READY sensing means disposed to sense a ready condition of the system with respect to filling a particular container;

a valve, having a plurality of ports, adapted to be connected between the supply and the said chamber, and between said chamber and dispensing means recited hereinbelow; and adapted and connected to effect bidirectionality of fluid flow to and from the metering piston and chamber; the said valve having a spool with a plurality of necked-down portions formed therein, and the said spool being driven, in response to the said functional signals, between two alternative positions corresponding to and inducing the two alternative directions of fluid flow to and from the metering piston and chamber;

dispensing means comprising:

means defining an orifice and a dispensing passageway connected with said valve for conducting the volumes of substance from the piston and chamber via said valve into such containers; and

orifice-control means, responsive to engagement of a component of the dispensing means with such container, for effecting discharge of such substance only in the presence of a container and for preventing admission of air via said orifice into the passageway; and

first functional-signal interconnection means between sensing means and spool valve, adapted to drive the valve spool to its position which initiates plunger motion toward the OUT sensing means only when the IN sensing means and CONTAINER READY sensing means are initially simultaneously actuated; and to drive the valve spool toward that position which initiates plunger motion toward the IN sensing means only if the OUT sensing means are actuated; whereby initiation of the first half-cycle of operation is contingent upon presence of a container, and initiation of the second half-cycle is contingent upon completion of the first half-cycle; and

second functional-signal interconnection means between the sensing means and a signal utilization means, for actuation of the utilization means if the SYSTEM READY sensing means are actuated but the IN sensing means are not actuated; whereby further system operation may be made contingent upon response to the signal-utilization means.

38. The system of claim **37**, also comprising:

indicator means for indicating to a human operator whether the spool valve is actuated and the cycle initiated.

39. The system of claim **38**, wherein:

the indicator means comprise a transparent wall section forming at least a portion of the wall of the spool valve.

40. The system of claim **38**, wherein:

the indicator means are responsive to functional-signal transmission from the IN sensing means.

41. The system of claim **38**, also comprising:

means for freeing the spool within the valve in the event the indicator means indicates stickage thereof.

42. The system of claim **37**, wherein:

the first functional-signal interconnection means between sensing means and spool valve are further adapted to drive the valve spool toward that position which initiates plunger motion toward the IN sensing means only if the OUT sensing means are actuated while simultaneously the said SYSTEM READY sensing means are not actuated;

whereby continual reciprocating operation of the spool and piston is inhibited if the system is stopped in a system-ready position, thereby to prevent multiple overfilling of a container.

43. The system of claim **37,** also comprising:

means for deactuating the CONTAINER READY sensing means when system operation is interrupted.

44. A system for filling containers with flowable substance, comprising:

supply means for storing a supply of such substance under pressure;

means defining a cylindrical chamber and at least one port at each end thereof;

a piston closely and slidably fitted within the chamber for motion between predetermined limits;

compliant means for effecting a sliding seal between the inner surface of the chamber and the outer surface of the piston, whereby the piston forms a movable wall cooperating with the first-mentioned defining means to define first and second subchambers, each having at least one port;

dispensing means for conducting such substance into such containers;

valve means comprising:

means defining a cylindrical barrel and at least five ports therein spaced along the length thereof;

a spool closely and slidably fitted within the barrel, and having at least two necked-down portions spaced along its length; the spool having at least two stable positions longitudinally within the barrel;

means for driving the spool between the two stable positions in response to arrival of the piston in the chamber at the said predetermined limits; and

means for effecting connection between the supply means, the ports of the valve barrel, the ports of the subchambers, and the dispensing means whereby the valve provides:

during a first half-cycle of operation, with the spool in one of its two stable positions, physical communication between the first subchamber and the supply means, whereby pressurized substance from the supply means entering the first subchamber forcibly moves the cylinder, enlarging the first subchamber and reducing the second subchamber; and provides physical communication between the second subchamber and the dispensing means, whereby reduction of the second subchamber forcibly moves such substance out of the second subchamber to the dispensing means; and

during a second half-cycle of operation, with the spool in the other of its two stable positions, physical communication between the second subchamber and the supply means, whereby pressurized substance from the supply means entering the second subchamber forcibly moves the cylinder, enlarging the second subchamber and reducing the first subchamber; and provides physical communication between the first subchamber and the dispensing means, whereby reduction of the first subchamber forcibly moves such substance out of the first subchamber to the dispensing means.

45. The system of claim **44,** wherein the spool-driving means comprises:

a supply of pressurized gas;

two additional ports, one at each end of the valve barrel, each communicating with a space within the barrel and defined in part by an end surface of the spool;

means for providing physical communication between the gas supply and the two additional ports; and

control means, responsive to operation of the piston in the chamber and other system functions, for operating upon the last-mentioned providing means so as to apply the pressurized gas selectively to one or the other end surface of the spool;

and also including provision for preventing leakage of pressurized gas into such substance and preventing leakage of such substance into the pressurized gas, comprising:

at each end of the barrel, two compliant seals arranged in series:

one seal exposed on one functional side to such pressurized substance and on another functional side to a gas at a reduced pressure; and

another seal exposed on one functional side to pressurized gas in one such space within the barrel and on another functional side to a gas at a reduced pressure;

whereby any leakage of such pressurized substance across the said one seal is only into the gas at reduced pressure and not into the pressurized gas spaces within the barrel; and any leakage of such pressurized gas across the said other seal is only into the gas at reduced pressure and not into the pressurized substance.

46. A system for filling containers with flowable substance, comprising:

means for storing a supply of such substance under positive pressure with respect to ambient;

a plurality of volumetric metering chambers, each with a bi-acting piston, for establishing controlled volumes of such substance, at positive pressure with respect to ambient, substantially equal to the volume through which the piston sweeps in operation, the chamber end walls being formed in such fashion as to squeeze any gas bubbles out of the chamber at the end of a piston stroke;

a plunger fixed to each piston and extending through an end wall of the corresponding chamber, and having at its end remote from the piston an actuating surface which engages pneumatic-control pushbutton valves;

means for effecting individual relative adjustment of each actuating surface and its corresponding pushbutton valves;

means for effecting common relative adjustment between the plurality of actuating surfaces and the corresponding pushbutton valves, during system operation;

a plurality of dispensing means, each comprising:

a closable nozzle which is higher than its corresponding metering chamber and which opens to dispense such substance in response to engagement of a component of the dispensing means with such container to be filled, and which is otherwise closed to prevent air from entering the system via the nozzle; and which prior to dispensing is moved, relative to the container to be filled, into a position such that the opening in the nozzle is below the opening of the container, and such that the opening in the nozzle is below the liquid level in the container after dispensing; and

suction means for aiding in removal of air from such container during dispensing and for removal of drops from the nozzle after dispensing, the drop-removal function being disabled during dispensing and the air-removal function being disabled after dispensing;

connection means between the supply, chambers and valves, establishing a flow path via each valve, at positive pressure relative to ambient:

from the supply to a first side of the corresponding piston, and from the second side of the same piston to the corresponding dispensing means, during a first half-cycle of operation; and

from the supply to the second side of the piston, and from the first side of the piston to the dispensing means, during a second half-cycle of operation;

gas-entrapment means disposed along the flow path between the supply and each valve, and comprising:

a slow-flow section of tubulation wherein any gas bubbles in the substance rise by their buoyancy to the top of the tubulation;

a dome juxtaposed to and communicating with the top of the slow-flow section, for accumulation of such bubbles; and

release means, responsive to the substance level within the dome, for releasing accumulated gas from the dome;

utilization means, responsive to pneumatic signals from the pushbutton valves and to other system elements, for halting system operation and inhibiting discharge of substance and the operational cycle of a piston in the event a container is not present in filling position at the corresponding one of the plurality of dispensing means; and for actuating an alarm to alert a human operator of such event; and

flow-rate adjustment means comprising apertures selectably insertable in the flow path to each dispensing means individually, permitting substantial equalization of the flow rates to all of the respective dispensing means.

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