



(11)

EP 3 725 734 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
21.10.2020 Bulletin 2020/43

(51) Int Cl.: **B67C 3/00** ^(2006.01) **B67C 3/28** ^(2006.01)

(21) Application number: **19305503.5**

(22) Date of filing: **18.04.2019**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
 GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
 PL PT RO RS SE SI SK SM TR**
 Designated Extension States:
BA ME
 Designated Validation States:
KH MA MD TN

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(54) A METHOD AND AN APPARATUS FOR FILLING A CONTAINER

(57) A method for filling a container (2) with a pourable product by means of a modulating valve (5) provided with a shutter (8) movable through a plurality of positions includes the steps of getting (504) a first current value indicative of the position of the shutter (8), getting (505) a second current value indicative of a pressure of the pourable product, controlling (509) the position of the shutter (8) based on a third current value indicative of an actual flow rate of the pourable product through the valve (5), providing (501) a first relation (R1; T1) between the pressure (8) and a reference flow rate of the pourable product that flows when the shutter (8) is at a given reference position, providing (503) a second relation (R2; T2) between the position of the shutter and a parameter defined by a ratio between the actual flow rate and the reference flow rate, determining (506) a fourth current value of the parameter through the second relation (R2; T2) according to the first current value, determining (507) a fifth current value of the reference flow rate through the first relation (R1; T1) according to the second current value, and computing (508) the third current value from the fourth current value and the fifth current value.

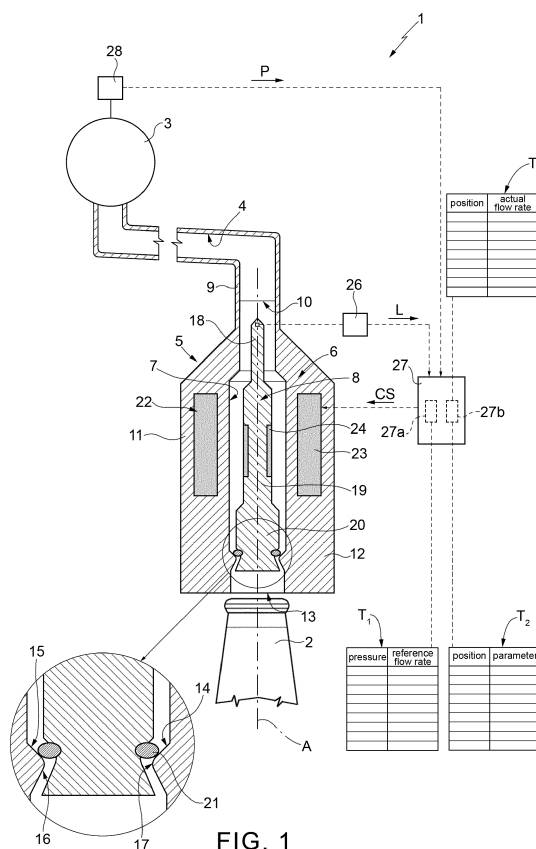


FIG. 1

Description

[0001] The present invention relates to a method and an apparatus for filling containers, for example bottles or the like, with a pourable product.

[0002] Filling machines are known, essentially comprising a carousel rotating around a vertical axis, a tank containing the pourable product, and a plurality of filling apparatus peripherally carried by the carousel, connected to the tank by means of respective circuits or ducts and conveyed from the carousel itself along a circular transfer path.

[0003] Each filling apparatus essentially comprises:

- a support element adapted to receive and hold in a vertical position a respective container; and
- a modulating filling valve arranged above the support element and configured to feed a pre-set volume of pourable product to the container, while moving along the transfer path due to the rotary movement of the carousel.

[0004] Typically, modulating filling valves of the known type essentially comprise:

- a vertical tubular body fixed to a peripheral portion of the carousel and defining a vertical flow channel for feeding the pourable product to a respective container to be filled, arranged below the tubular body itself; and
- a shutter which engages in a sliding manner the tubular body and is mobile inside the channel, in order to open or close, in a variable manner, an outflow passage of the pourable product towards the respective container.

[0005] In particular, the tubular body has a longitudinal axis parallel to the axis of the carousel and ends at a lower end with an axial outlet opening fluidically communicating, in use, with an end opening defined by an upper edge of the respective container to be filled.

[0006] The channel defined by the tubular body comprises a stretch having a constant section, usually cylindrical, and a stretch with variable section, positioned above the outlet opening and narrowing in the direction of the latter, up to a minimum-diameter section.

[0007] In modulating filling valves of a known type, the shutter is movable within the channel of the tubular body in a plurality of positions ranging between a position of maximum closure, wherein the shutter closes in a sealed manner the minimum-diameter section, in order to interrupt the flow of the pourable product towards the outlet opening, and a position of maximum aperture, wherein the shutter delimits together with the minimum-diameter section, an annular outflow passage of maximum aperture fluidically communicating with the outlet opening, so as to allow the flow of the pourable product towards the end opening of the respective container.

[0008] Therefore, the shutter is movable between the position of maximum closure and the position of maximum aperture through a plurality of intermediate opening positions, defining with the minimum-diameter section respective intermediate annular outflow passages with increasing dimensions.

[0009] In order to control the movement of the shutter between the aforementioned positions, the modulating filling valves comprise an actuator, typically of the electromagnetic type.

[0010] In particular, the actuator comprises a coil arranged inside the tubular body and magnetically coupled to one or more permanent magnets appropriately included in the shutter.

[0011] Typically, the aforementioned filling apparatus further comprise a flow rate sensor, preferably a flowmeter, configured for measuring the flow rate of the pourable product passing through the channel of the tubular body and for generating a correlated flow rate signal, and a position sensor configured for measuring the position of the shutter inside the channel and for generating a correlated position signal. The filling apparatus of the known type furthermore comprise, a control unit configured for receiving the aforementioned flow rate and position signals and for controlling the movement of the shutter as a function of said flow rate and position signals.

[0012] In detail, the coil of the actuator receives, in use, a command signal from the control unit and produces, according to a known mode of operation typical of the coils, a corresponding magnetic field adapted to move the shutter by means of magnetic interaction with the permanent magnets included in the shutter itself.

[0013] In this manner, it is possible to control the opening of the modulating valve in correlation with the flow rate passing through the valve itself and the position of the shutter inside the channel measured by the respective sensors.

[0014] However, the applicant has observed that the measurement of the above-mentioned flow rate obtained by means of a flowmeter, is particularly inefficient for controlling the opening of the modulating valves currently in use in the field, since the output rates of the flow rate signals generated by the known flowmeters are at least an order of magnitude greater than process times of current control units. In fact, the known flowmeters output flow rate samples with time periods of approximately 50 milliseconds, whereas the control unit can update the command signal for the modulating valve with a rate of approximately 0.5 milliseconds. Therefore, an individual modulating filling valve receives the updated command signal from the control unit with a considerable delay, due to the slowness of the flow rate measurements.

[0015] The aim of the present invention is to provide a method and an apparatus for filling a container that allow overcoming the aforementioned drawbacks, related to the known apparatus, in a simple and economic manner.

[0016] According to the present invention, this aim is achieved by a method and an apparatus for filling a con-

tainer, as defined in the appended set of claims.

[0017] For a better understanding of the present invention, preferred non-limiting embodiments will now be described, purely by way of example and with the help of the attached drawings, wherein:

- Figure 1 schematically shows, with parts removed for clarity, an apparatus for filling a container, according to the invention; and
- Figure 2 schematically shows, with parts removed for clarity, a testing apparatus for extracting information about a modulating valve being part of the apparatus of Figure 1;
- Figures 3, 4 and 5 are diagrams showing characteristic curves of the modulating valve; and
- Figure 6 is a block diagram showing steps of the method according to the invention.

[0018] With reference to Figure 1, number 1 indicates as a whole, an apparatus for filling, to a predetermined level, a respective container 2 with a pourable product, for example still water.

[0019] In particular, the apparatus 1 is connected, in a fluidic manner and by means of a duct 4, to a tank 3 (only partially illustrated) containing the pourable product.

[0020] As can be seen in Figure 1, the apparatus 1 comprises a filling valve 5 of the modulating type, which can be selectively activated to control the outflow of the pourable product towards the container 2 to be filled. In this configuration, the container 2 is positioned below and spaced from the valve 5, in order to receive from the latter, the pourable product by the action of gravity.

[0021] Therefore, the apparatus 1 is configured for carrying out a "contactless filling operation".

[0022] Alternatively, the container 2 may be supported in fluid tight contact against the corresponding valve 5, so that a "contact filling operation" may be carried out.

[0023] The valve 5 essentially comprises:

- a tubular body 6, having a vertical axis A and defining a central flow channel 7 configured for feeding the pourable product into the container 2; and
- a shutter 8 slidably engaging the tubular body 6 and movable inside the channel 7 in order to enable or prevent the outflow of the pourable product towards the respective container 2 to be filled.

[0024] In particular, the tubular body 6 has an upper end portion 9 provided with an inlet opening 10 axially configured to receive the pourable product from the tank 3 through the duct 4, an intermediate portion 11, and a lower end portion 12 ending with an outlet opening 13 axially configured for feeding the pourable product into the respective container 2.

[0025] With reference to the preferred embodiment shown in Figure 1, the channel 7 comprises, at the lower end portion 12 of the tubular body 6, a portion with variable section 14 having two frustum conical stretches 15,

16. In particular, the stretch 15 is positioned upstream of the stretch 16 in respect to the feeding direction of the pourable product inside the channel 7, namely arranged superiorly with respect to the stretch 16 itself, and has a section tapering towards the latter; the stretch 16 instead has a diameter increasing from the stretch 15 up to the outlet opening 13. Therefore, the two stretches 15, 16 define between one another, a narrowed section 17, namely a minimum-diameter section.

[0026] As can be seen in Figure 1, the shutter 8 is axially fitted within the channel 7 of the tubular body 6.

[0027] In particular, the shutter 8 comprises an upper end portion 18, an intermediate portion 19, having a diameter greater than the diameter of the upper portion 18 and axially extending therefrom in the direction of the outlet opening 13, and a shaped terminal portion 20, configured for cooperating with the portion of the tubular body 6 defining the portion with variable section 14 of the channel 7.

[0028] In particular, the terminal portion 20 is provided with a sealing ring 21, preferably an O-ring made in elastomeric material, configured for selectively cooperating in a fluid-tight manner with the narrowed section 17 of the channel 7, in order to prevent or enable the outflow of the pourable product towards the outlet opening 13 and, therefore, into the container 2 to be filled.

[0029] For this purpose, the shutter 8 is movable within the channel 7 of the tubular body 6 through a plurality of positions ranging, in particular, between:

- a position of closure, wherein the shutter 8 seals in a fluid tight manner, by means of the sealing ring 21, the narrowed section 17 of the channel 7, in order to prevent the outflow of the pourable product towards the outlet opening 13; and
- a position of maximum aperture, wherein the shutter 8 delimits together with the narrowed section 17 of the channel 7 an annular passage of maximum outflow fluidically communicating with the outlet opening 13, in order to allow the outflow of the pourable product towards the container 2.

[0030] Practically, the shutter 8 is movable, between the aforementioned positions of closure and maximum aperture, through a plurality of intermediate opening positions, which are virtually unlimited and define respective intermediate outflow annular passages with gradually increasing openings, as the shutter 8 proceeds from the position of closure to the position of maximum aperture.

[0031] In other words, during its movement from the position of closure along axis A, the shutter 8 delimits with the narrowed section 17 an outflow passage with variable dimension adapted to control the filling speed of the container 2.

[0032] In order to control the movement of the shutter 8 between the aforementioned positions, the valve 5 comprises an actuator 22, preferably of the electromagnetic type.

[0033] In particular, the actuator 22 comprises a coil 23 arranged around channel 7 at the intermediate portion 11 of the tubular body 6 and configured to be magnetically coupled to one or more permanent magnets 24 appropriately included in the intermediate portion 19 of the shutter 8.

[0034] Conveniently, as can be seen in Figure 1, the apparatus 1 further comprises:

- a position sensor 26, preferably a Hall sensor, configured for measuring a quantity indicative of the position of the shutter 8 along the axis A within the channel 7 and for generating a position signal L correlated with the measured quantity;
- a pressure sensor 28 configured for measuring a quantity indicative of a pressure of the pourable product, in particular the supply pressure to the valve 5 or, in other words, the pressure inside the tank 3, and configured for generating a pressure signal P correlated with the measured quantity; and
- a control unit 27, which is coupled to both the position sensor 26 and the pressure sensor 28 and is configured for receiving the position and pressure signals L, P, as well as for controlling the activation of the actuator 22 as a function of such signals L, P.

[0035] During the filling of the container 2, at a given instant, the position sensor 26 and the pressure sensor 28 detect respective current values of the corresponding measured quantities; therefore, while time goes ahead, both the position signal L and the pressure signal P may consist of respective time series of values, in particular according to a given sampling frequency, wherein each value of the position signal L is associated to a relative value of the pressure signal P.

[0036] Otherwise, the pressure sensor 28 may detect a single value to form the pressure signal P, wherein such a single value is associated to each of the values forming the position signal L.

[0037] Preferably, the position sensor 26 is arranged at the upper portion 18 of the shutter 8.

[0038] Control unit 27 comprises a memory portion 27a storing a first relation between values of the quantity measurable through the pressure sensor 28 and respective values of a reference flow rate of the pourable product, which flows through the valve 5 when the shutter 8 is at a given reference position.

[0039] In other words, control unit 27 is provided with prior information about the specific influence that pressure has on the flow rate flowing through the valve 5 for a given constant reference position of the shutter 8.

[0040] The reference position may be any one of the infinite intermediate opening positions of the shutter 8 or, possibly, the position of maximum opening. Such a reference position, preferably, is stored in the memory portion 27a.

[0041] With greater detail, the above first relation is based on a two-dimensional table T1 (Figure 1), which

is preferably stored in the memory portion 27a and contains a plurality of flow rate values that are globally associated to the same reference position and one by one associated to respective sample pressure values, which fall within the range of the pressure sensor 28.

[0042] In other words, when the position of the shutter 8 coincides with the reference position and the pressure of the pourable product takes one of the sample pressure values, the flow rate of pourable product flowing through the valve 5 is expected, in view of the technical properties of the valve 5, to take a corresponding flow rate value contained in table T1.

[0043] Preferably, sample pressure values span uniformly a pressure interval, such that the differences between consecutive sample pressure values are all equal to one another and, for example, equal to $50 \cdot 10^{-3}$ bar.

[0044] Specifically, the above first relation is defined by a corresponding analytical expression, e.g. a polynomial of the second order, which fits the flow rate values contained in table T1 as a function of pressure, i.e. of the quantity measured by the pressure sensor 28.

[0045] Figure 3 shows an exemplary continuous curve R1 representing graphically the first relation: the horizontal axis represents the pressure of the pourable product, i.e. the supply pressure to the valve 5, whereas the vertical axis represents the reference flow rate. In Figure 3, the symbols q_{ref} and p indicate respectively the reference flow rate and the pressure of the pourable product.

[0046] Clearly, differently from what just disclosed without any loss of generality, the first relation may be defined directly by the table T1, which can be interpolated in known manners by the control unit 27 as a function of any pressure value for the extraction of a corresponding value of the reference flow rate, although the latter value is not contained within table T1.

[0047] Indeed, like the corresponding analytical expression, table T1 represents by itself a mathematical model of the valve 5, i.e. defines a plurality of discrete estimates of the flow rate of the pourable product flowing through the valve 5 as a function of the pressure when the shutter 8 is at the reference position.

[0048] Table T1 and/or the related analytical expression are peculiar to valve 5 and predetermined, in the sense that at least one of them is present in the memory portion 27a before any filling operation has been started through filling apparatus 1.

[0049] Table T1 and/or the related analytical expression, i.e. the first relation, may be for instance provided to control unit 27 thanks to a testing procedure of the valve 5, as it will be disclosed in the following with greater detail, or simply be provided by the producer of the modulating valve 5 based on a prior knowledge of the technical properties of the valve 5.

[0050] In addition to memory portion 27a, control unit 27 further comprises another memory portion 27b storing a second relation between values of the quantity measured by the position sensor 26 and respective values of a parameter, which is defined by a ratio between the ac-

tual flow rate (i.e. the flow rate flowing through the valve 5 as a function of the pressure of the pourable product and the position of the shutter 8) and the reference flow rate, at the reference position of the shutter 8, according to the same pressure leading to the actual flow rate.

[0051] In particular, the following equation holds:

$$C(x) = \frac{q_{act}(p, x)}{q_{ref}(p)}$$

where the symbols C , p , x , q_{ref} , q_{act} indicates respectively the parameter, the pressure, the position of the shutter 8, the reference flow rate and the actual flow rate.

[0052] After having performed several experiments, the Applicant discovered that for each position of the shutter 8, the parameter takes respective different values that, on the other hand, do not change if the pressure of the pourable product changes. In other words, the Applicant discovered that the parameter is invariant with respect to pressure variations.

[0053] Hence, control unit 27 is provided with further prior information, which this time is about the specific influence that the position of the shutter 8 has on the flow rate flowing through the valve 5 for any pressure of the shutter 8.

[0054] In this manner, while the control unit 27 receives the position signal L and the pressure signal P , the same control unit 27 is provided with sufficient information, thanks to the first and the second relation, to estimate reliably the actual flow rate. Indeed, the reference flow rate is related to the pressure signal P , according to the first relation, and the actual flow rate is related to the reference flow rate and to the position signal L , according to the second relation.

[0055] The second relation is based, in particular, on another two-dimensional table $T2$, which is preferably stored in the memory portion 27b and contains a plurality of values of the parameter respectively associated to sample position values, which fall within the range of the position sensor 26.

[0056] In other words, when the shutter 8 reaches a position corresponding to one of the sample position values, the parameter is expected, in view of the technical properties of the valve 5, to take a corresponding value contained in table $T2$.

[0057] Preferably, sample position values span uniformly a position interval, such that the differences between consecutive sample position values are all equal to one another and, for example, equal to 0.1 mm. In particular, the bounds of the position interval coincide with the position of closure and the position of maximum aperture.

[0058] Specifically, the above second relation is defined by a corresponding analytical expression, e.g. a polynomial of the second order, which fits the values of the parameter contained in table $T2$ as a function of the

position of the shutter, i.e. of the quantity measured by the position sensor 26.

[0059] Figure 4 shows an exemplary continuous curve $R2$ representing graphically the second relation: the horizontal axis represents the position of the shutter 8, whereas the vertical axis represents the parameter. In Figure 4, the symbols C and x indicate respectively the actual flow rate and the pressure of the pourable product.

[0060] Clearly, differently from what just disclosed without any loss of generality, the second relation may be defined directly by the table $T2$, which can be interpolated in known manners by the control unit 27 as a function of any position taken by the shutter 8 for the extraction of a corresponding value of the parameter, although the latter value is not actually contained within table $T2$.

[0061] Indeed, like the corresponding analytical expression, table $T2$ represents by itself a mathematical model of the valve 5, i.e. defines a plurality of discrete estimates of the parameter as a function of the position of the shutter 8, independently of the pressure of the pourable product.

[0062] Table $T2$ and/or the related analytical expression are peculiar to valve 5 and predetermined, in the sense that at least one of them is present in the memory portion 27b before any filling operation has been started through filling apparatus 1.

[0063] Table $T2$ and/or the related analytical expression, i.e. the second relation, may be provided to control unit 27 in the same way table $T1$ and/or the related analytical expression are provided, i.e. thanks to a testing procedure of the valve 5 or to prior knowledge of the technical properties of the valve 5.

[0064] With greater detail, the second relation is even derivable from a third relation, conveniently stored in the memory portion 27b, between values of the quantity measurable through the position sensor 26 and respective values of the actual flow rate when the pressure takes a given reference pressure.

[0065] The reference pressure may be any positive pressure value within the range of the pressure sensor 28. Such a reference pressure, preferably, is stored in the memory portion 27b.

[0066] In particular, the third relation is based on a two dimensional table $T3$, which is preferably stored in the memory portion 27b and contains a plurality of flow rate values that are globally associated to the same reference pressure and one by one associated to respective sample position values, which more preferably are the same for which table $T2$ is built.

[0067] More in particular, between the flow rate values that are contained in table $T3$, a special value is the one associated to the sample position value that is equal to the aforementioned reference position. Such a special value can be, nevertheless, separately stored in the memory portion 27b if not included in table $T3$.

[0068] Table $T2$ is related to table $T3$, and thus derivable therefrom, since the values of the parameter con-

tained in table T2 are defined by respective ratios between the flow rate values contained in table T3 and the special value.

[0069] Specifically, the third relation is defined by a corresponding analytical expression, e.g. a polynomial of the second order, which fits the flow rate values contained in table T3 as a function of the position of the shutter, i.e. the quantity measured by the position sensor 26.

[0070] Thus, the second relation is related to the third relation, and hence derivable therefrom, since the two respective analytical expressions are equal each other, except for a constant, which is the special value divided to the whole analytical expression of the third relation for obtaining the analytical expression of the second relation.

[0071] Figure 5 shows a plurality of continuous curves R3 that are respectively associated to a plurality of possible reference pressures and represent graphically respective possible third relations that may be each used for deriving the second relation: the horizontal axis represents the position of the shutter 8, whereas the vertical axis represents the actual flow rate. In Figure 5, the symbols q_{act} and x indicate respectively the actual flow rate and the position of the shutter 8; moreover, the symbol x_{ref} indicates here an exemplary reference position, to which a plurality of possible special values (here indicated with the symbol q_{spec}) correspond according to the represented third relations.

[0072] In fact, each of the possible third relations shown in Figure 5 is related to a different reference pressure, but all the resultant second relations that are derived from such third relations result coincident to each other, since the parameter is invariant with respect to pressure variations.

[0073] Clearly, differently from what just disclosed without any loss of generality, since table T2 may define the second relation, even table T3 may analogously define the third relation.

[0074] Table T3 and/or the related analytical expression, i.e. the third relation, may be provided to control unit 27 in the same way table T1 and/or the related analytical expression are provided, i.e. thanks to a testing procedure of the valve 5 or to prior knowledge of the technical properties of the valve 5.

[0075] During the filling of one container 2, control unit 27 is configured for extracting, according to a given sampling frequency, one current value of the quantity measurable through position sensor 26 and one current value of the quantity measurable through pressure sensor 28, at each sample time, respectively from signals L, P received from the position sensor 26 and the pressure sensor 28.

[0076] Then, at each sample time, control unit 27 is configured for determining a current value of the parameter through the second relation.

[0077] For instance, in particular, control unit 27 is configured for accessing table T2 with the extracted current value from the position signal L and for interpolating table T2 to extract therefrom the current value of the parameter.

ter.

[0078] Alternatively, control unit 27 is configured for computing the current value of the parameter by substituting the extracted current value from the position signal L into the analytical expression defining the second relation.

[0079] Furthermore, at each sample time, control unit 27 is configured for determining a current value of the reference flow rate through the first relation.

[0080] For instance, in particular, control unit 27 is configured for accessing table T1 with the extracted current value from the pressure signal P and for interpolating table T1 to extract therefrom the current value of the reference flow rate.

[0081] Alternatively, control unit 27 is configured for computing the current value of the reference flow rate by substituting the extracted current value from the pressure signal P into the analytical expression defining the first relation.

[0082] Then, control unit 27 is configured to determine, for each sample time, a current value of the actual flow rate from the current values of the parameter and of the reference flow rate.

[0083] Precisely, control unit 27 perform the product of the current value of the parameter with the current value of the reference flow rate, so as to obtain the current value of the actual flow rate.

[0084] In this manner, while time goes ahead during the filling operation of one container 2, the control unit 27 updates a flow rate signal Q, which consists of a time series of the determined current values of the actual flow rate.

[0085] According to the diagram illustrated in Figure 1, the coil 23 receives, in use, a command signal CS from the control unit 27, correlated with the flow rate signal Q, and consequently produces, according to a known mode of operation of the coils, an electromagnetic field adapted to magnetically interact with the permanent magnets 24 included in the shutter 8, so as to move the shutter 8 itself inside the channel 7.

[0086] In detail, based on the flow rate signal Q, control unit 27 determines a set position signal L_{set} that is sample-by-sample compared with the position signal L, which defines, therefore, a feedback signal for closed-loop controlling the actual position of the shutter 8.

[0087] In particular, the command signal CS is proportional to the difference between the feedback position signal L and the set position signal L_{set} and, more in particular, to the integral and the derivative thereof; in other words, control unit 27 implements a so-called PID ("partial-integrative-derivative") control for controlling the position of the shutter 8.

[0088] Specifically, the set position signal L_{set} includes:

- a opening ramp with a predetermined slope from the position of closure to a set position selected between the position of closure and the position of maximum aperture;

- a constant portion at the set position; and
- a closure ramp with a predetermined slope from the set position to the position of closure.

[0089] Control unit 27 determines the end of the constant portion, which coincides with the beginning of the closure ramp, during filling by performing numerical integration of the flow rate signal Q until a filling threshold is reached. Here, the end of the constant portion occurs at the time sample when the filling threshold is reached.

[0090] The slopes of the opening and closure ramps are held in any one of the memory portions 27a, 27b of control unit 27, whereas the end of the constant portion is determined during the filling.

[0091] For instance, the filling threshold coincides with the desired filling level for the container 2 and is held in any one of the memory portions 27a, 27b; preferably, the filling threshold is updated after each filling by subtracting a filling lag to such desired filling level.

[0092] The filling lag is defined as the volume of pourable product supplied to the container 2 during the closure ramp and the same filling lag is computed by control unit 27 through a numerical integration of a portion of the flow rate signal Q , which corresponds to the closure ramp.

[0093] In this manner, it is possible to control the opening of the valve 5 in correlation with the position of the shutter 8 inside the channel 7 and the related actual flow rate passing through the valve 5 itself, without providing apparatus 1 with any sensor for measuring such flow rate.

[0094] During the filling operation carried out, without any interruptions of production, on a plurality of containers 2, the control unit 27 commands the position of shutter 8 along the axis A as a function of the position signal L and the flow rate signal Q , the latter being generated from the determined current values of the actual flow rate.

[0095] As it clearly appears from the above, there is no need of measuring the actual flow rate of the pourable product through the valve 5; therefore, apparatus 1 is devoid of any flow rate sensor.

[0096] Conveniently, tables T1, T3 can be built during respective testing operations by means of a testing apparatus 101, which allows the performance of a plurality of measurements of the actual flow rate of a testing fluid through the valve 5, prior to the first filling of a container 2 and for a plurality of given positions of the shutter 8 and pressures of the testing fluid, specifically supply pressures to the valve 5.

[0097] Preferably, as shown in Figure 2, testing apparatus 101 is defined by the apparatus 1 with the addition of a flow rate sensor, in particular a flowmeter 125 coupled to the apparatus 1, and the possible replacement of control unit 27 with a different control unit 127.

[0098] Testing apparatus 101 is connected in a fluidic manner and by means of a duct 104, to a tank 103 (only partially illustrated) containing the testing fluid.

[0099] Flowmeter 125 is connected to control unit 127 and is configured to measure the actual flow rate of the

testing fluid passing through the valve 5, generate a flow rate signal Q_{meas} correlated with the measured actual flow rate, and send the signal Q_{meas} to the control unit 127.

[0100] Preferably, the flowmeter 125 is arranged in correspondence of the duct 104, in order to measure, during the testing operations, the actual flow rate of the testing fluid passing through the duct 104 itself and direct it towards the valve 5.

[0101] To perform a first testing operation and, accordingly, build table T3, the tank 103 is filled with a quantity of testing fluid, e.g. water, having the above-mentioned reference pressure.

[0102] Then, after the tank 103 is filled, control unit 127 progressively sends to coil 23 a plurality of commands CS' correlated to a respective plurality of desired position values of the shutter 8, i.e. desired opening grades of the valve 5, so that the shutter 8 moves accordingly inside the channel 7. Each of the desired position values corresponds to one of the above-mentioned sample position values.

[0103] Each time the shutter 8 reaches one of those desired positions, control unit 127 associates the current value measured by the position sensor 26 and the current flow rate value measured by the flowmeter 125.

[0104] Accordingly, control unit 127 stores such current value and such current flow rate value in table T3.

[0105] Then, to perform a second testing operation and accordingly, build table T1; the tank 103 is repeatedly refilled with respective quantities of testing fluid at distinct desired pressures equal to the above-mentioned pressure sample values, while the position of the shutter 8 is maintained fixed at the aforementioned reference position.

[0106] In correspondence of each refill of the tank 103, control unit 127 associates the current value measured by the pressure sensor 28 and the current reference flow rate value measured by the flowmeter 125.

[0107] Accordingly, control unit 127 stores such current value and such current reference flow rate value in table T1.

[0108] Therefore, once tables T1, T3 are completely filled, the table T2 can be possibly derived by control unit 127 from table T3 and all tables T1, T2, T3 are respectively transferred to the memory portions 27a, 27b of the control unit 27.

[0109] Possibly, only tables T1, T3 or only tables T1, T2 may be transferred to the respective memory portions 27a, 27b.

[0110] Furthermore, control unit 127 may be configured to fit analytical expressions to table T1 and to at least one of tables T2, T3, such that the latter expressions may be transferred to the respective memory portions 27a, 27b.

[0111] After the testing operations are completed, the flowmeter 125 is removed from testing apparatus 101 to obtain the apparatus 1, which is connected in a fluidic manner to the tank 3 by means of the duct 4, so as to

become ready for use.

[0112] It should be noted that tables T1, T2, T3 may be occasionally updated by repeating the testing operations after the performance of a filling operation, for example during a programmed or undesired machine downtime.

[0113] In the latter case, apparatus 1 is separated from tank 3 and connected to tank 103 via the duct 104, in which flowmeter 125 is arranged and fixed thereto.

[0114] In such a manner, tables T1, T2, T3 are adapted to the actual technical properties of the valve 5 after intensive use thereof.

[0115] In the remainder of the disclosure, an exemplary method for filling a container 2 by means of the valve 5 and, more in particular by means of the apparatus 1, is disclosed with reference to Figure 6.

[0116] According to a step 501, the first relation is provided, in particular to control unit 27, between values of the quantity measurable through the pressure sensor 28 and respective values of the reference flow rate.

[0117] Additionally, in another step 502, the third relation is provided, in particular to control unit 27, between the values of the quantity measurable through the position sensor 26 and respective values of the actual flow rate when the pressure of the pourable product takes the reference pressure.

[0118] Then, in a further step 503, possibly comprising the second step 502, the second relation is provided and, in particular, determined by control unit 27 based on the third relation and the aforementioned special value; the second relation being between the values of the quantity measurable through the position sensor 26 and respective values of the parameter.

[0119] According to further steps 504, 505, the current values of the respective quantity measurable through the sensors 26, 28, are get and more specifically received by the control unit 27 from the sensors 26, 28.

[0120] After the step 503, the current value of the parameter is determined, in particular by the control unit 27, through the second relation according to the current value of the quantity measurable through the position sensor 26 (step 506).

[0121] Moreover, after the step 501, the current value of the reference flow rate is determined, in particular by the control unit 27, through the first relation (step 507) according to the current value of the quantity measurable through the pressure sensor 28.

[0122] Hence, according to step 508, the current value of the actual flow rate is computed from the current value of the reference flow rate and the current value of the parameter.

[0123] Thus, the position of the shutter 8 is controlled based on the determined current value of the actual flow rate (step 509).

[0124] From the foregoing, the advantages of the apparatus 1 and of the method according to the invention are apparent.

[0125] Definitively, thanks to the absence of any flow

rate sensor, which are efficiently substituted by tables T1, T2, T3, the actuator 22 of the shutter 8 of the valve 5 receives the command signal CS from the control unit 27 at a speed of many orders of magnitude greater in respect to the hypothetical case in which the command signal CS would have been a function of flow rate values measured by a flow rate sensor, such as, for instance, flowmeter 125.

[0126] In fact, in this latter case, the control unit 27 should have waited to receive the flow rate signal Q directly from the flowmeter 125 before being able to control the movement of the shutter 8.

[0127] Moreover, thanks to the discovered invariance of the parameter to pressure variations, it is possible to gain complete information about the technical properties of valve 5 with a strongly reduced quantity of testing data.

[0128] In addition, the possibility of obtaining different filling laws as a function of different pressures within the tank 103 allows a flexibility increase of the apparatus 1 when filling operations needs to be carried out at different pressure levels.

[0129] It is thus clear that modifications and variations can be made to the apparatus 1 and to the method described and illustrated herein, without departing from the scope of protection defined by the claims.

[0130] For example, tables T1, T2, T3 may be replaced by one or more general databases.

[0131] Table T2 and the related analytical expression may lack within control unit 27; in the latter case, the second relation would be based on a ratio between the special value and the flow rate values, in particular extracted by interpolation from table T3 or obtained by substitution into the related analytical expression, as a function of corresponding values of the quantity measurable through the position sensor 26.

[0132] In other words, the control unit 27 would be configured to extract from table T3 or to compute through the corresponding analytical expression the current value of the actual flow rate at the reference pressure as a function of the current value of the quantity measurable through the position sensor 26. Moreover, the control unit 27 would be further configured to compute a ratio between the same current value of the actual flow rate at the reference pressure and the special value to determine the current value of the parameter.

[0133] In the above context, the special value may also be computed by the control unit 27 by extraction from table T3 or through substitution of the reference position into the related analytical expression.

[0134] Moreover, memory portions 27a, 27b may coincide to each other.

[0135] The testing operations may be performed through a testing apparatus including a modulating valve, which is distinct from modulating valve 5 but has the same technical properties of the latter. Moreover, the testing operations performed with the aid of the testing apparatus 101 may include procedures different from those described above; in particular, the order of the flow rate

measurements may be any appropriate order from the practical point of view.

[0136] Furthermore, the pressure sensor 28 may be used for measuring the pressure of the pourable product at the outlet opening 13 or anywhere else in the channel 7 or in the duct 4.

[0137] Position sensor 26 and pressure sensor 28 are not strictly necessary and, therefore, may be lacking. The current values of the respective measurable quantities may be gotten, for instance, from the command signal CS, as regard the position of the shutter 8, or known a priori, as regard the pressure, more specifically the supply pressure.

[0138] Furthermore, control unit 27 may comprise control unit 127, so that no replacement of control units 27, 127 occurs.

[0139] Eventually, the shape of the containers 2 may be different from the one of a bottle and the pourable product may be a food product or any other kind of industrial product.

Claims

1. A method for filling a container (2) with a pourable product by means of a modulating valve (5) provided with a shutter (8) movable through a plurality of positions; the method comprising the steps of:

- getting (504) a first current value of a first quantity indicative of the position of said shutter (8);
- getting (505) a second current value of a second quantity indicative of a pressure of said pourable product;
- controlling (509) the position of said shutter (8) based on a third current value indicative of an actual flow rate of said pourable product flowing through said valve (5) ;

characterized by further comprising the steps of:

- providing (501) a first relation (R1; T1) between values of said second quantity and respective values of a reference flow rate of said pourable product flowing through said valve (5) when said shutter (8) is at a given reference position;
- providing (503) a second relation (R2; T2) between values of said first quantity and respective values of a parameter, being defined by a ratio between said actual flow rate and said reference flow rate and being invariant with respect to pressure variations;
- determining (506) a fourth current value of said parameter through said second relation (R2; T2) according to said first current value;
- determining (507) a fifth current value of said reference flow rate through said first relation (R1; T1) according to said second current value;

and

- computing (508) said third current value from said fourth current value and said fifth current value.

2. The method of claim 1, wherein the step of getting (504) said first current value comprises performing a corresponding measurement of said first quantity; and/or wherein the step of getting (505) said second current value comprises performing a corresponding measurement of said second quantity.

3. The method of claim 1 or 2, wherein said pressure is the supply pressure to said valve (5).

4. The method of any one of the foregoing claims, wherein the step of providing (501) said first relation (R1; T1) comprises providing at least one first object between a first look-up table (T1) and a first analytical expression (R1); said first object associating said values of said second quantity to said values of said reference flow rate.

5. The method of any one of the foregoing claims, wherein the step of providing (503) said second relation (R2; T2) comprises providing (502) a third relation (R3; T3) between said values of said first quantity and respective values of said actual flow rate at a given reference pressure; said second relation (R2; T2) being based on said third relation (R3; T3) and on a special value of said actual flow rate corresponding to said reference position and said reference pressure.

6. The method of claim 5, wherein the step of providing (502) said third relation (R3; T3) comprises providing a second look-up table (T3) associating said values of said first quantity to said values of said actual flow rate at the given reference pressure; wherein said second relation (R2; T2):

- is based on a ratio between said values of said actual flow rate, extracted from said second look-up table (T3) in association with said values of said first quantity, and said special value; or
- is based on a third look-up table (T2) derived from said second look-up table (T3) based on said special value; said third look-up table (T3) associating said values of said first quantity and said values of said parameter.

7. The method of claim 5, wherein the step of providing (502) said third relation (R3; T3) comprises providing a second analytical expression (R3) associating said values of said first quantity to said values of said actual flow rate at the given pressure; wherein said second relation (R2; T2):

- is based on a ratio between said values of said actual flow rate, obtained through said second analytical expression (R2) as a function of said values of said first quantity, and said special value; or
 - is based on a third analytical expression (R2) derived by dividing said special value to the whole said second analytical expression (R3).
8. The method of any one of claims from 1 to 4, wherein the step of providing (503) said second relation (R2; T2) comprises providing at least one second object between a fourth look-up table (T2) and a fourth analytical expression (R2); the second object associating said values of said first quantity to said values of said parameter.
9. An apparatus (1) for filling a container (2) with a pourable product, the apparatus comprising a modulating valve (5) provided with a shutter (8) movable through a plurality of positions; the apparatus further comprising:
- first electronic means (26) configured for getting during the filling a first current value of a first quantity indicative of the position of said shutter (8);
 - second electronic means (28) configured for getting during the filling a second current value of a second quantity indicative of a pressure of said pourable product; and
 - a control unit (27), which:
 - a) is coupled to both said first and second electronic means (26, 28) for receiving said first and second current value; and
 - b) is configured to control the position of said shutter (8) during the filling based on a third current value indicative of an actual flow rate of said pourable product flowing through said valve (5);
- characterized in that** said control unit (27) comprises:
- a first memory (27a) storing a first relation (R1; T1) between values of said second quantity and respective values of a reference flow rate of said pourable product flowing through said valve (5) when said shutter (8) is at a given reference position; and
 - a second memory (27b) storing a second relation (R2; T2) between values of said first quantity and respective values of a parameter, being defined by a ratio between said actual flow rate and said expected flow rate and being invariant with respect to pressure variations;

and **in that** said control unit (27) is further configured to:

- determine a fourth current value of said parameter through said second relation (R2; T2) according to said first current value;
 - determine a fifth current value of said reference flow rate through said first relation (R1; T1) according to said second current value; and
 - compute said third current value from said fourth current value and said fifth current value.
10. The apparatus of claim 9, being devoid of flow rate sensors.
11. The apparatus of claim 9 or 10, wherein said first electronic means (26) comprises a position sensor configured to detect said first current value; and/or wherein said second electronic means (28) comprises a pressure sensor configured to detect said second current value.
12. The apparatus of any one of claims from 9 to 11, wherein said first memory (27a) stores at least one first object between a first look-up table (T1) and a first analytical expression (R1), on which first object said first relation (R1, T1) is based; the first object associating said values of said second quantity to said values of said reference flow rate.
13. The apparatus of any of claims from 9 to 12, wherein:
- said second memory (27b) stores a third relation (R3; T3) defined by a second look-up table (T3) associating said values of said first quantity to values of said actual flow rate at a given reference pressure;
 - said control unit (27) is configured to extract from said second look-up table (T3) a special value of said actual flow rate corresponding to said reference position and said reference pressure, and/or said special value is stored within said second memory (27b);
 - said second relation is based on a ratio between said values of said actual flow rate, extracted from said second look-up table (T3) in association with said values of said first quantity, and said special value;
- and wherein said control unit (27) is further configured to:
- access said second look-up table (T3) with said first current value and accordingly extract from said second look-up table (T3) a sixth current value of said actual flow rate at the given reference pressure; and
 - determine said fourth current value through

said second relation by computing a ratio between said sixth current value and said special value.

14. The apparatus of any of claims from 9 to 12, wherein: 5

- said second memory (27b) stores a third relation (R3; T3) defined by a second analytical expression (R3) associating said values of said first quantity to values of said actual flow rate at a given reference pressure; 10
- said control unit (27) is configured to obtain from said second analytical expression (R3) a special value of said actual flow rate corresponding to said reference position and said reference pressure, and/or said special value is stored within said second memory (27b); 15
- said second relation is based on a ratio between said values of said actual flow rate, obtained through said second analytical expression (R3) as a function of said values of said first quantity, and said special value; 20

and wherein said control unit (27) is further configured to: 25

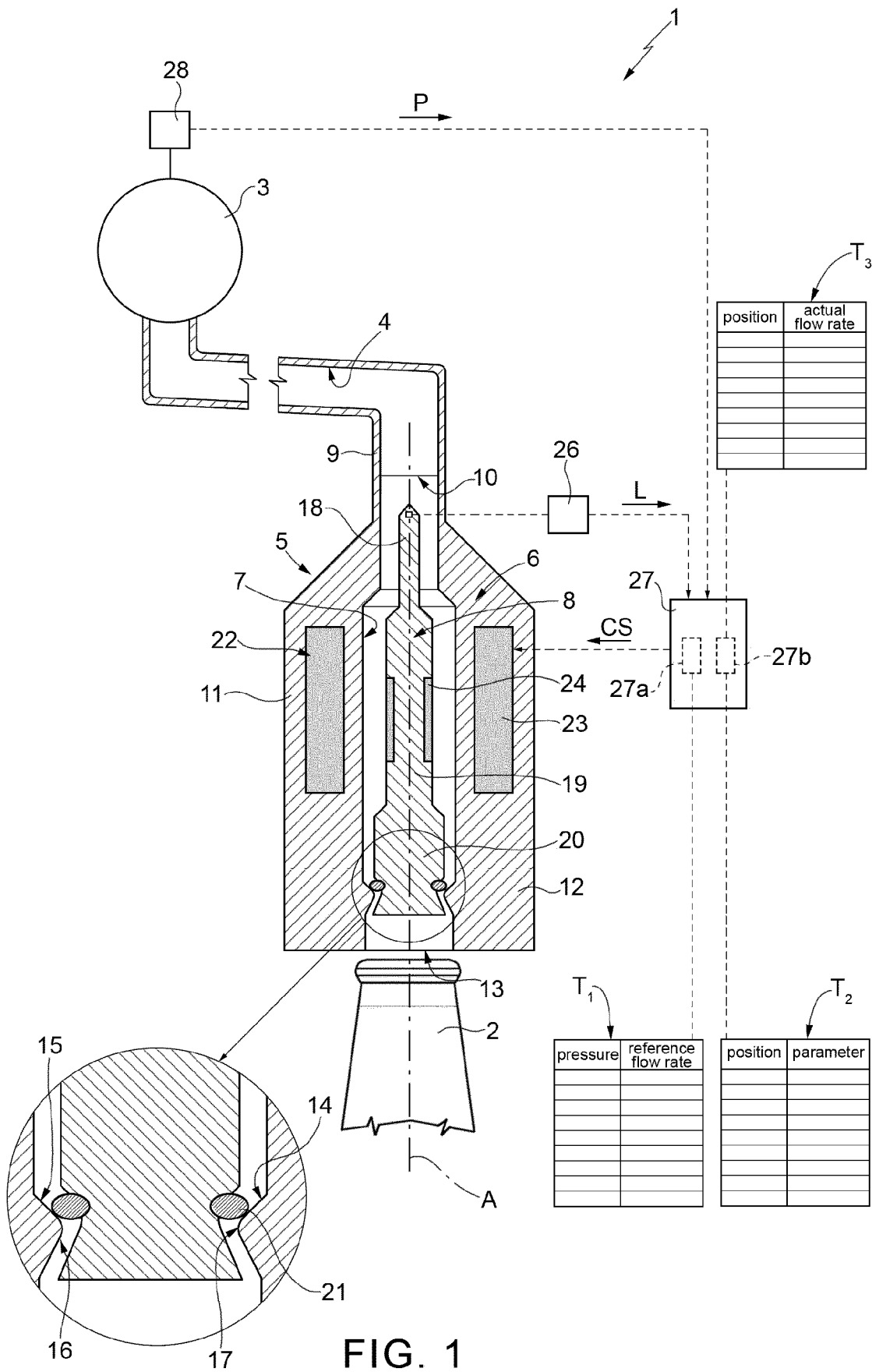
- compute a sixth current value of said actual flow rate at the given reference pressure through said second analytical expression (R3) as a function of said first current value; and 30
- determine said fourth current value through said second relation by computing a ratio between said sixth current value and said special value. 35

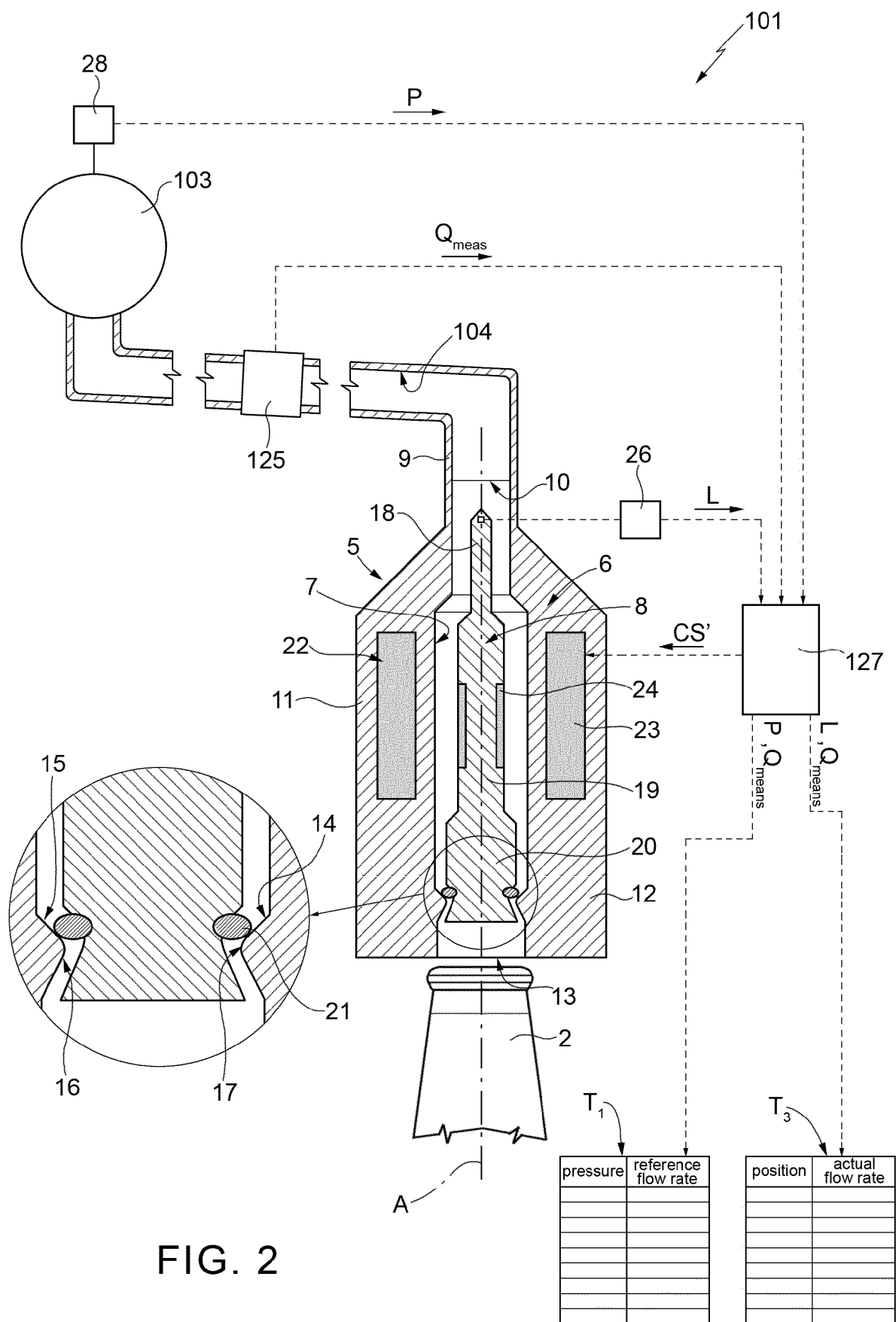
15. The apparatus of any one of claims from 9 to 12, wherein said second memory (27b) stores at least one second object between a third look-up table (T2) and a third analytical expression (R2), on which second object said second relation (R2; T2) is based; 40
the second object associating said values of said first quantity to said values of said parameter. 45

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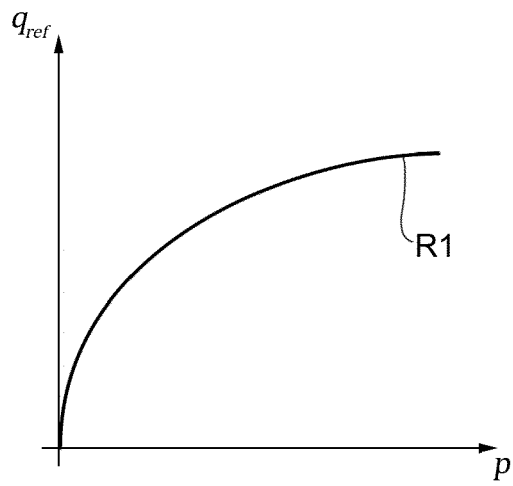


FIG. 3

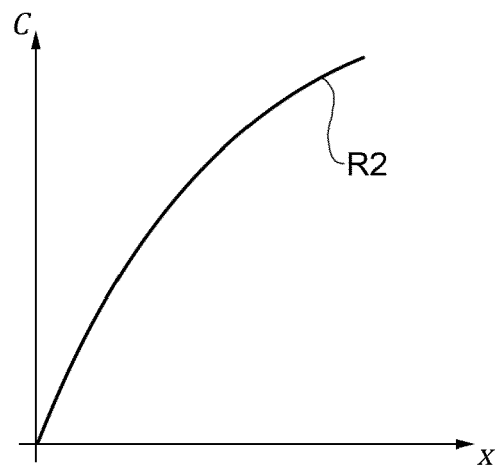


FIG. 4

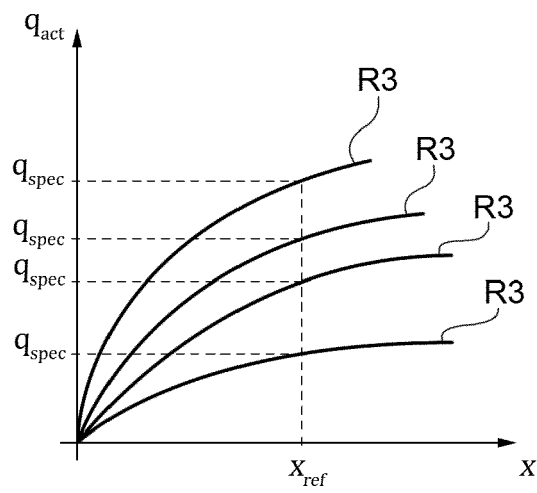


FIG. 5

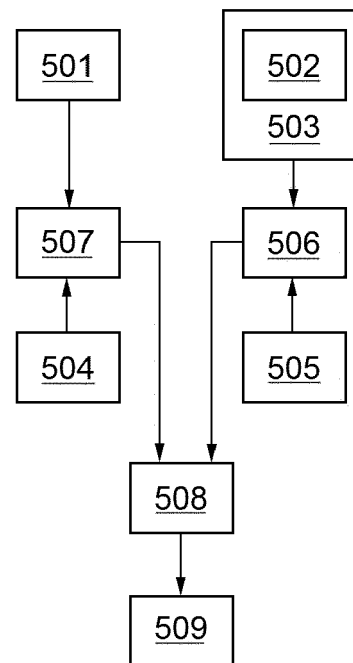


FIG. 6



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