

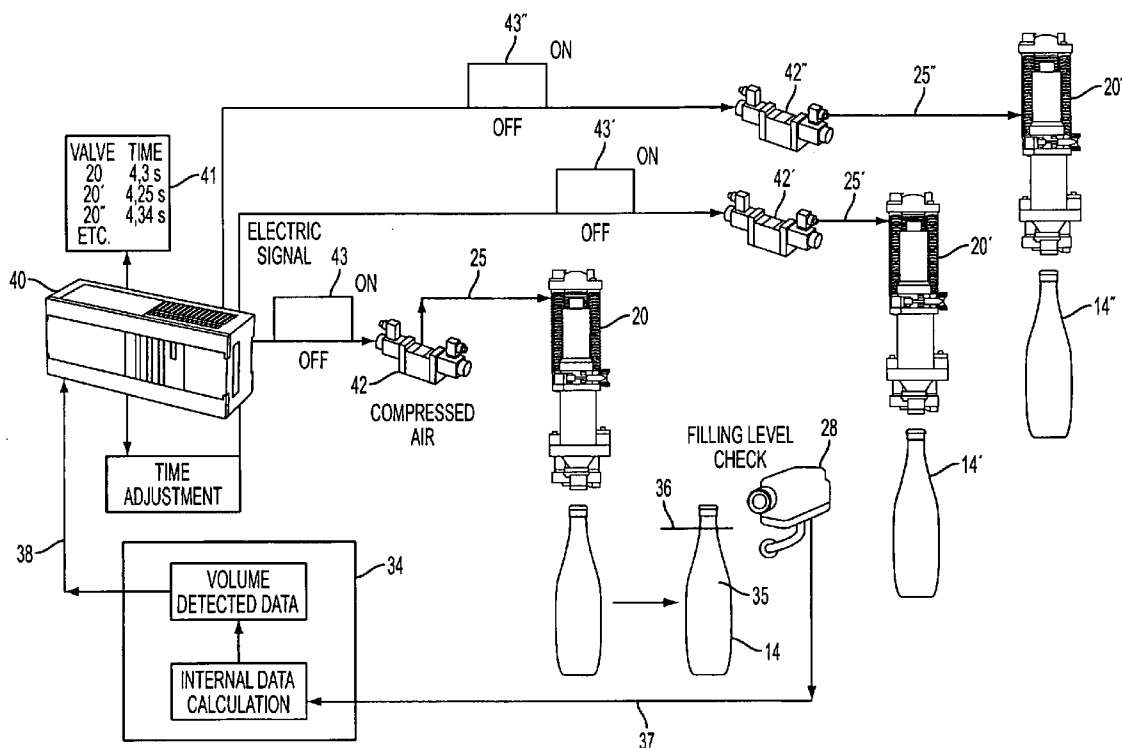


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(19) **United States**(12) **Patent Application Publication**
Cochran et al.(10) **Pub. No.: US 2007/0107801 A1**(43) **Pub. Date: May 17, 2007**(54) **BOTTLE FILLING MACHINE WITH
SENSOR AND METHOD THEREOF****Publication Classification**(51) **Int. Cl.**
B65B 43/42 (2006.01)(52) **U.S. Cl.** **141/153**(75) Inventors: **Don W. Cochran**, Cleveland, OH (US);
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(FR)(57) **ABSTRACT**

A filling apparatus and method including a carrier for transporting containers and having a plurality of valves, each of the valves being opened for an individual, specific period of time to control a flow of liquid into the respective containers, while the containers are transported by the carrier. An exit feed path transports the containers after the containers have been filled, and a sensor, such as a camera, detects a level of liquid in the respective containers, while the containers are on the exit feed path. The sensor produces a signal that is stored as data representing the level of liquid for the individual containers. The data is then tracked and used for valve optimization. A period of time that each individual valve is opened for subsequent fillings is adjusted based on the signal and the historical performance of each valve.

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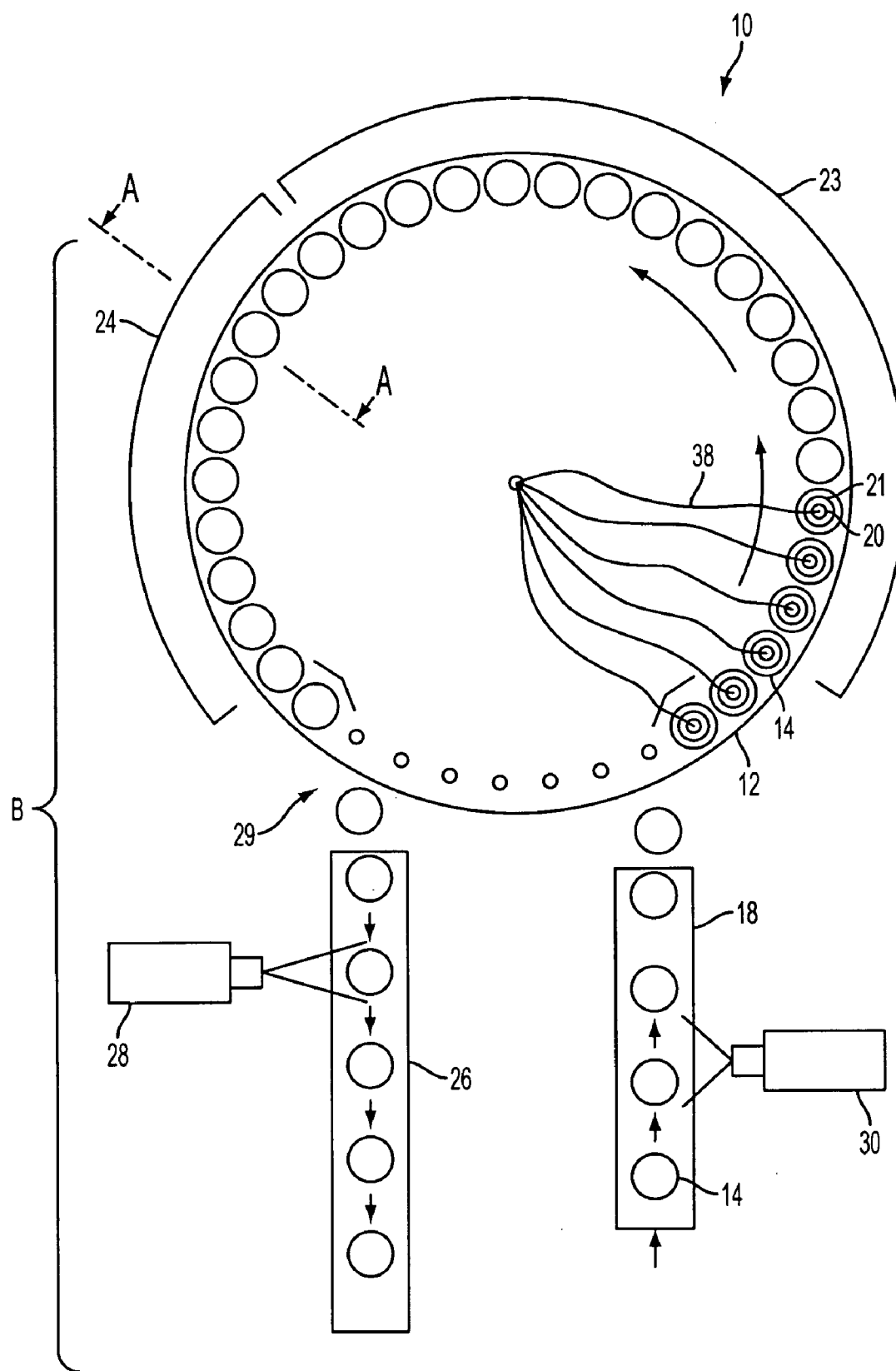


FIG. 1

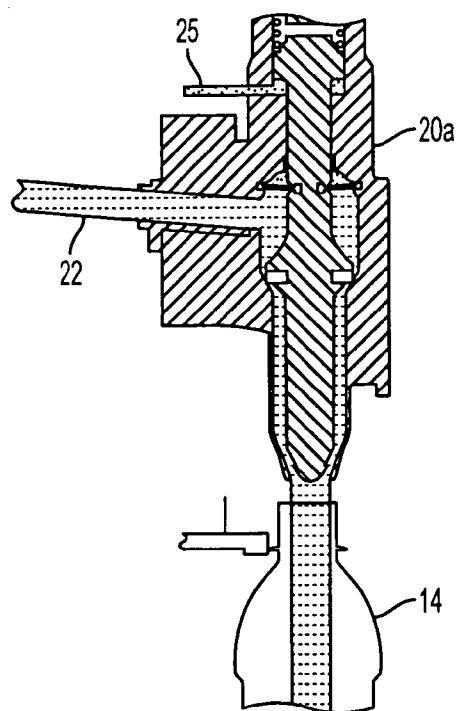


FIG. 2A

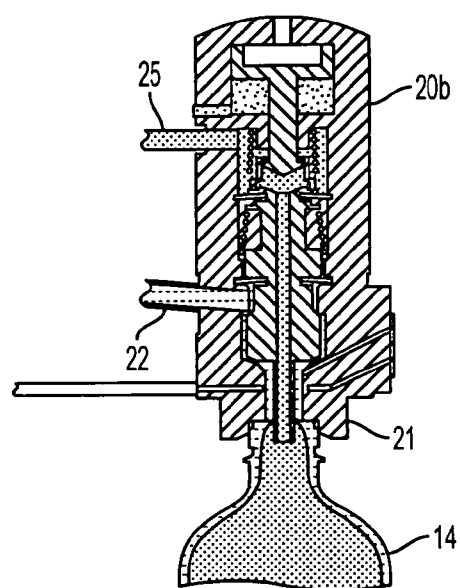
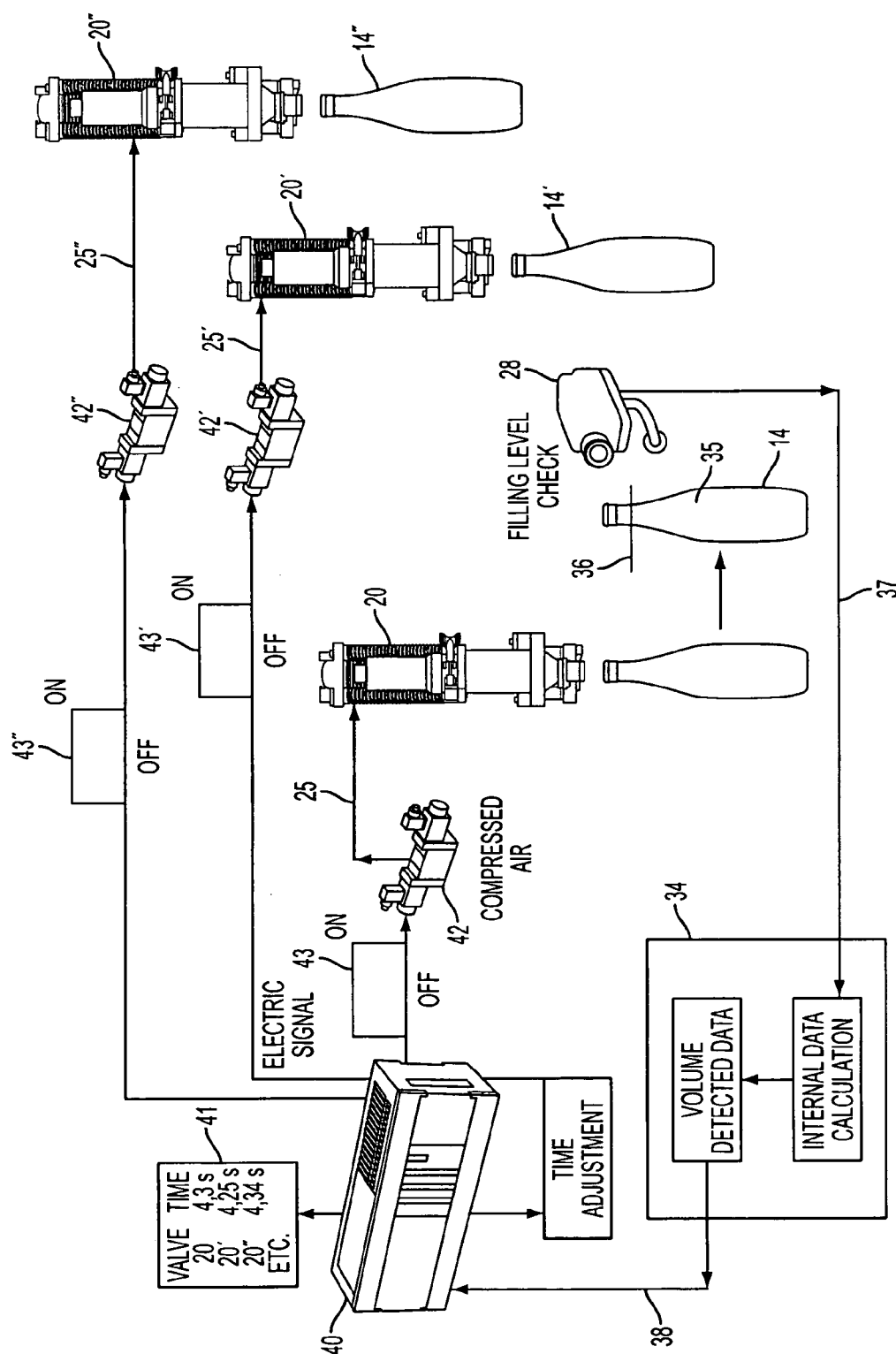


FIG. 2B



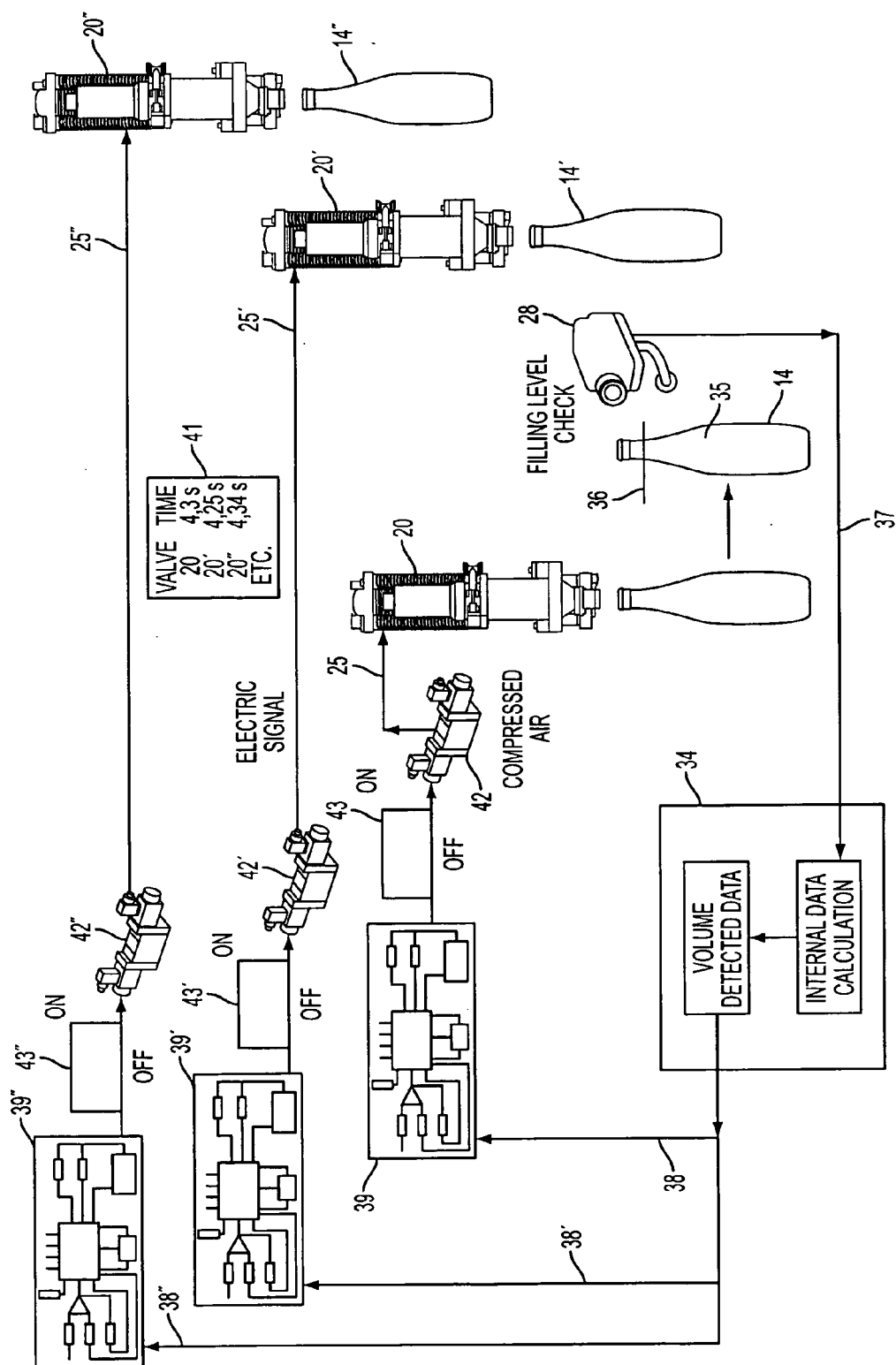


FIG. 4

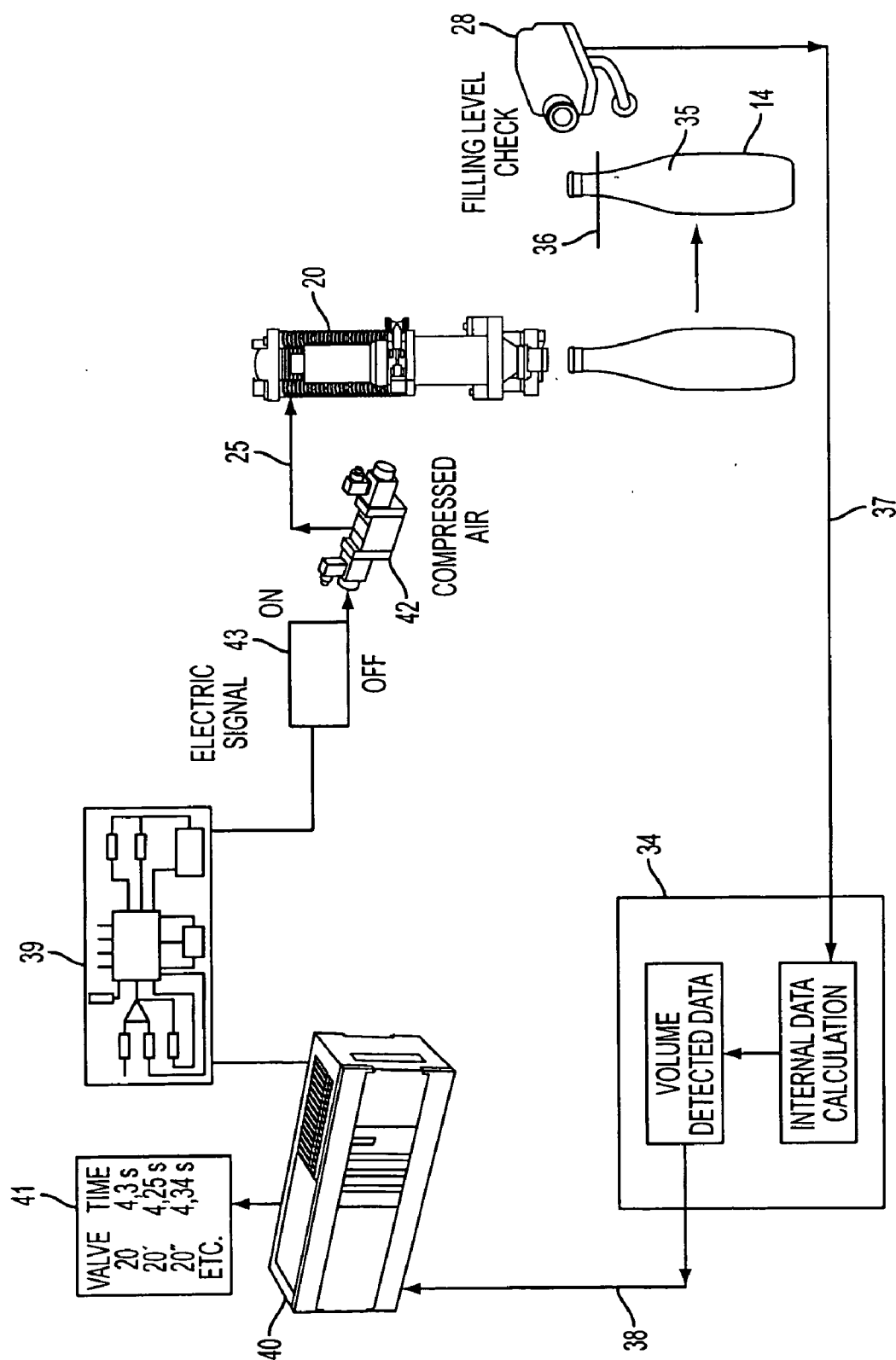
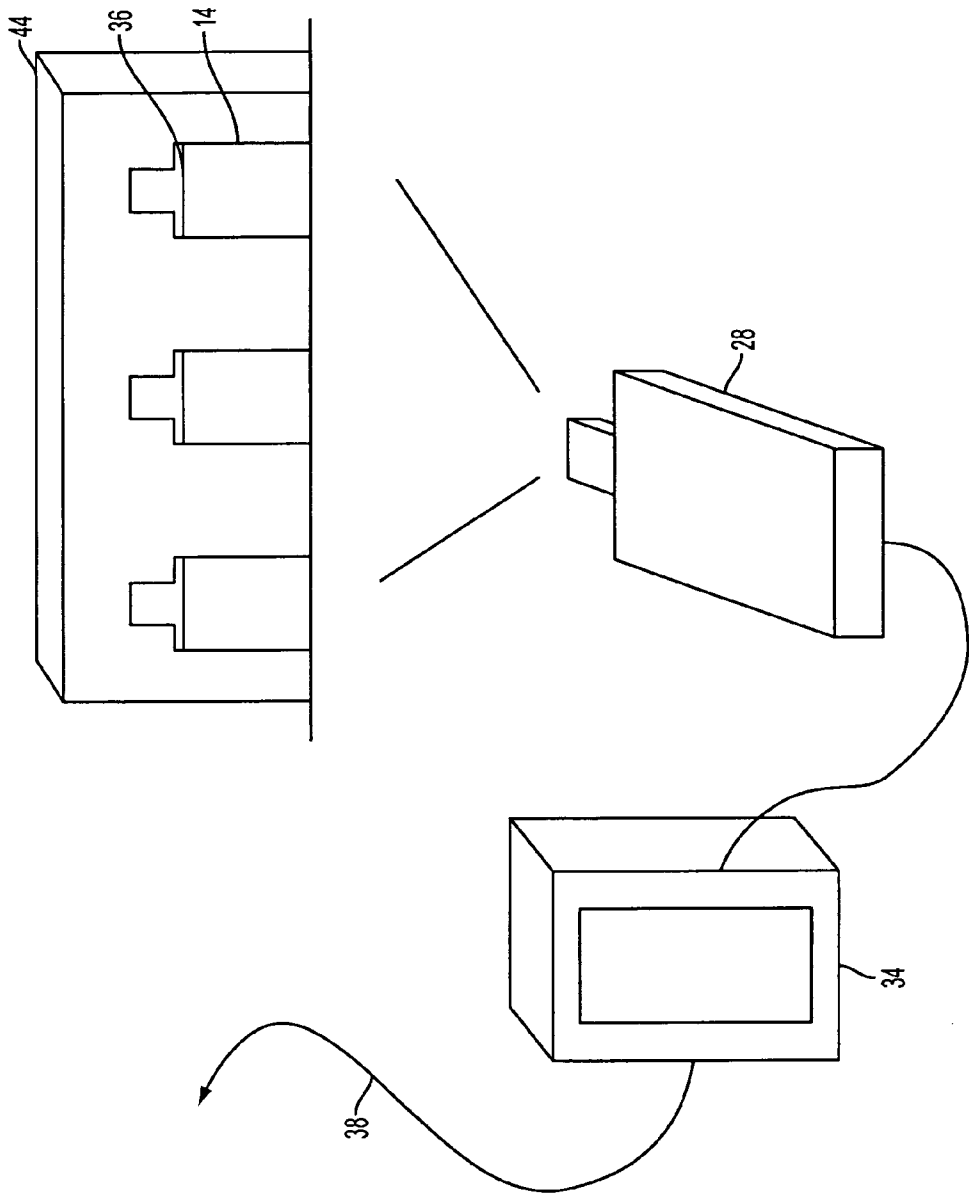


FIG. 5



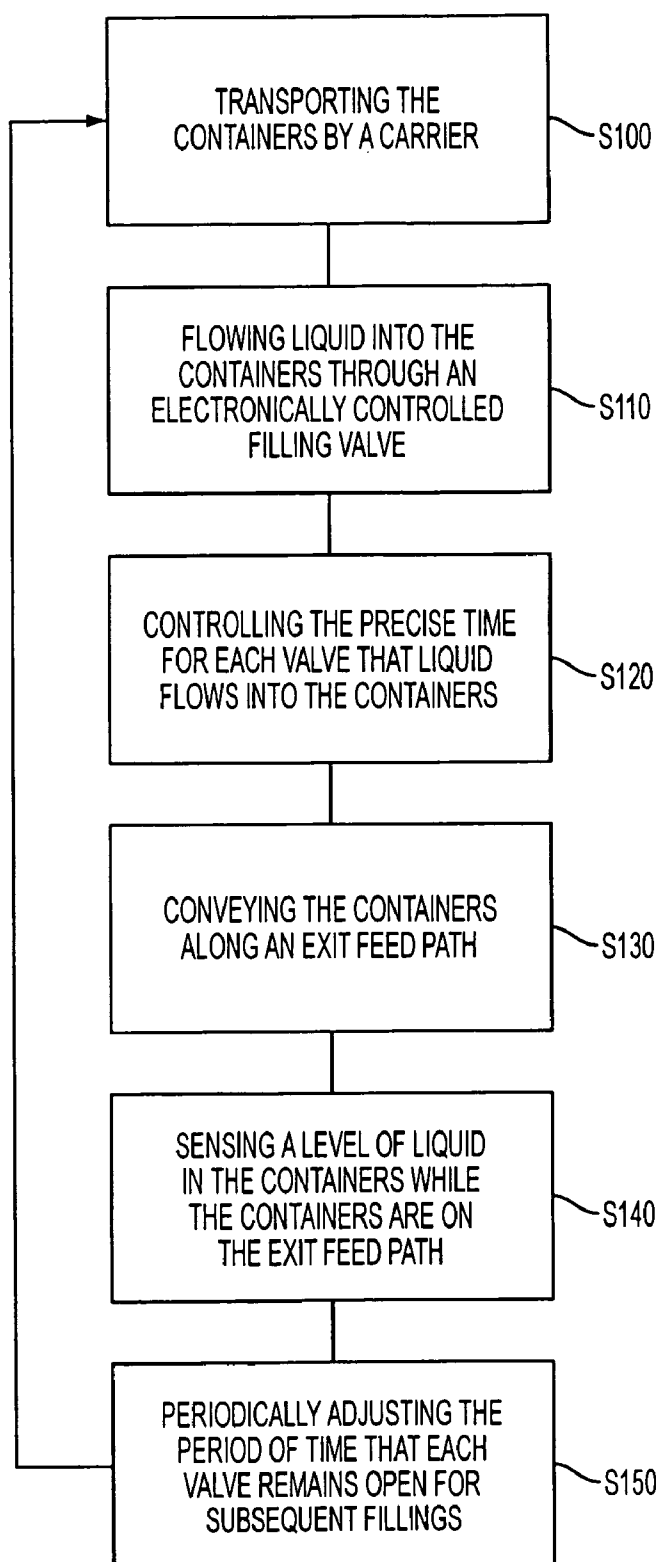


FIG. 7

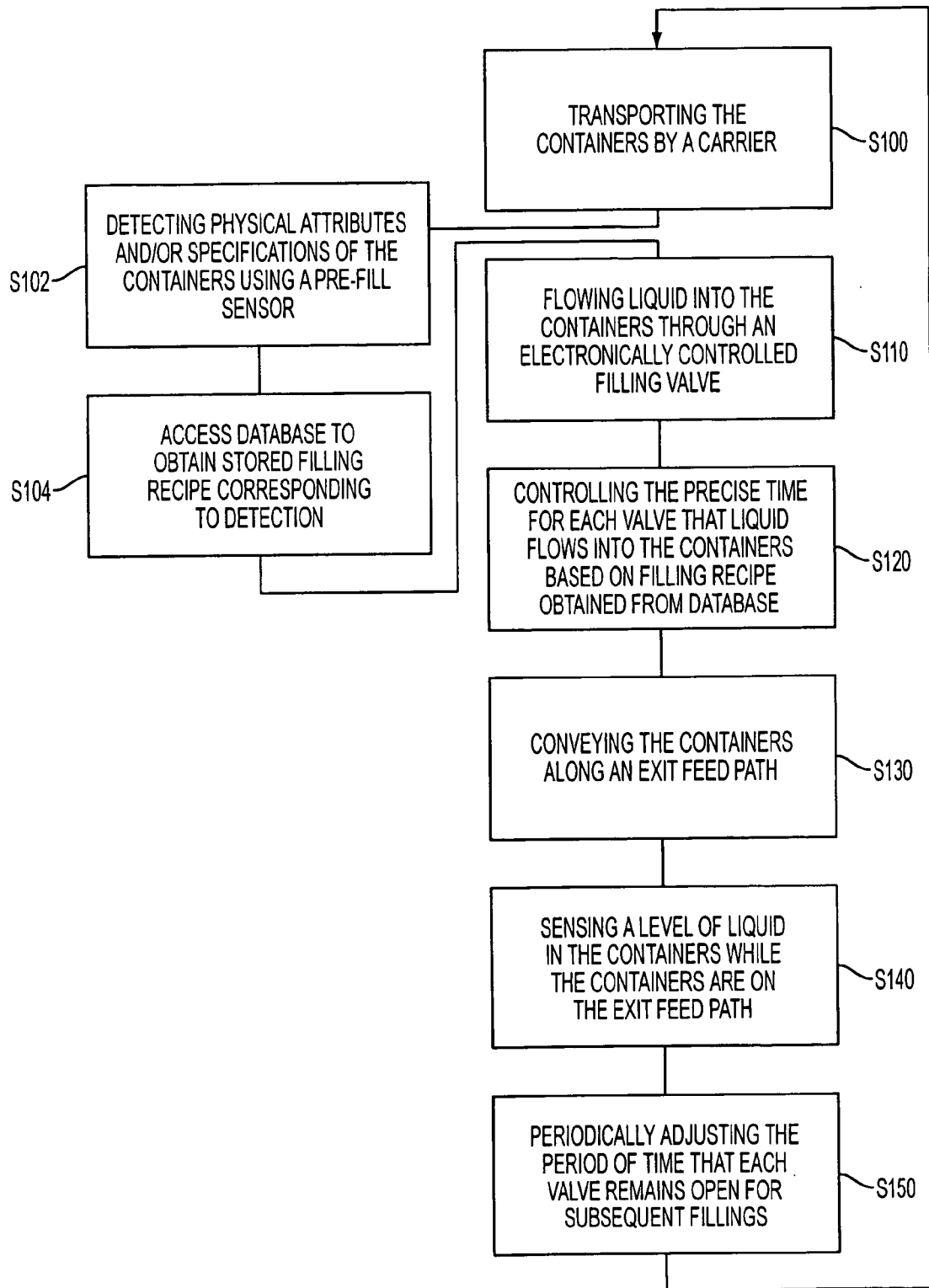


FIG. 8

BOTTLE FILLING MACHINE WITH SENSOR AND METHOD THEREOF**BACKGROUND OF THE INVENTION****[0001] 1. Field of the Invention**

[0002] Apparatuses and methods consistent with the present invention relate generally to regulating the dispersion of liquid into a container. More specifically, the invention relates to detecting a level of the liquid in the container, so as to obtain data and appropriately adjust a valve used to regulate the flow of the liquid.

[0003] 2. Description of the Related Art

[0004] In general, the bottling of beverages, sauces, liquid spices, etc., requires adjusting the bottling amount within a predetermined range. For example, it is known to regulate an amount of flow into a container using cam actuated filling valves, wherein containers are conveyed along circular path on a carrier, while being filled via nozzles that direct fluid or other material contents downwardly into the containers. In such a configuration, a carousel rotates to move the nozzles synchronously with the passing containers and the cam moves the nozzles downwardly to engage against or near the containers. Correct positioning with respect to a container and the rotational location of the carousel causes the filler to discharge into the container. However, such a cam arrangement is susceptible to various types of mechanical wear and misadjustment leading to inaccurate or inconsistent filling levels. In addition, a skilled technician is needed to adjust, maintain, and calibrate a substantial number of cam operated devices, which can result in increased costs, lower productivity, and increased labor. Stopping to make such mechanical adjustments or to change to a new filling job also contributes to additional down-time on the filling line, which is very expensive in terms of lost production.

[0005] It is also known in the industry to use so-called electric valve filling machines. In such machines, the filling valves are actuated electrically instead of mechanically. In most such machines, the valve is triggered or controlled electrically while an actual motive force for moving the valve into the actuated position is performed pneumatically. In most cases, the air pressure is used to overcome a mechanical spring pressure in order to open the valve. When the air pressure is exhausted, the spring returns the valve to its closed position. To gain the long term filling consistency that is required in the market, most such machines rely upon an electronic flow control sensor to verify that the correct amount of liquid has passed through the valve and into the container such that the valve can then be closed. Conventional electric valve filling machines have incorporated either volumetric flow sensors or mass flow sensors, depending on the type of liquid material being filled into the containers and which technology is appropriate for sensing the particular liquid. Typically, an electronic flow sensor is used at each valve. Because the flow sensors are relatively expensive, it becomes a substantial expense to build machines that have the same number of costly flow sensors as filling valves.

[0006] In addition, apparatuses and methods have been proposed for detecting and controlling an amount of liquid during the filling process. For example, U.S. Pat. No. 5,427,161 discloses to fill bottles by sensing an appropriate

time to shut a filling valve by using a camera to provide image based monitoring of a container. The camera provides image data of the container while it is being filled and, on the basis of the observed image data, a computer determines, in real-time, when to stop filling each container. However, this process requires a complex, close integration between the camera's findings and the valve control electronics to effect a precise shut-off. In addition, because the camera is actually viewing the containers as they are being filled, turbulence is induced during the imaging period. If the turbulence is not consistent or the system is lacking a means to correct for the turbulence, such image based monitoring could vary and be inaccurate. Also, the camera is not infinitely fast and must snap images periodically. Even with present day cameras, there is an amount of inaccuracy due to factors such as, illumination levels, camera scan speed, image transmission rate, band-widths, image analysis time, and other latencies that necessarily occur inside a computer driven imaging system. This type of system must, by definition, have a large field of view so it can take multiple images while the container passes through the field of the camera's view so the system can interpolate between the images to determine when the valve should close. The inherently larger field of view reduces systemic resolution since the number of pixels in the camera is spread over a larger view area. The container is inherently viewed from different angles for each image snap which has a detrimental effect on the quality of the image. In effect, prior systems require a larger or specially adapted light source, eliminate the ability to have an optimum view angle and require hardware and/or software to do additional algorithmic work to account for turbulence and differences in the scene.

[0007] It is also known to use a partial scan from a camera in order to reduce the time necessary to take the image and improve accuracy. However, measurements from the image are still limited by the speed of the camera and require high speed electronic "hand-shaking" with valve control electronics, such that the system will not tolerate any level of indeterminacies in the time that elapses from the initial image capture to sending a valve shut-off signal, resulting in increased expense and complexity.

SUMMARY OF THE INVENTION

[0008] Illustrative, non-limiting embodiments of the present invention overcome the disadvantages described above and other disadvantages. Also, the present invention is not required to overcome the disadvantages described above and the other disadvantages, and an illustrative, non-limiting embodiment of the present invention may not overcome any of the disadvantages.

[0009] An exemplary aspect of present invention is to provide a filling method and device that is capable of adjusting flow amounts based on monitoring current and/or past filling levels. It is an additional aspect to provide a filling method and device which could be augmented by other sensory inputs, besides the fill levels, to improve filling performance.

[0010] An exemplary embodiment of the present invention provides a filling apparatus including a carrier for transporting containers and at least one valve which is opened for a period of time to control a flow of liquid into the containers while the containers are transported by the

carrier. The invention may be implemented in machines that have more than one valve, but it can be practiced with as few as one valve. In general, typical rotary filling machines may have from 20 to 180 valves, with the higher speed and higher production machines utilizing the larger numbers of valves.

[0011] An exit feed path can be used to convey the containers after the containers have been filled and a sensor subsystem detects a level of liquid in the containers, while the containers are on the exit feed path, such that the sensor produces a signal which represents the level of liquid and corresponds to each respective filling valve. A period of time that each valve is opened for subsequent fillings may be adjusted based on one or more such historical measurement signals.

[0012] In further accordance with the invention, information pertaining to the level of liquid in a first group of the containers is obtained by the sensor to adjust the period of time that the valve remains open, and information pertaining to the level of liquid in a second group of the containers, filled by a second valve, is obtained to adjust a period of time that the respectively associated second valve remains open.

[0013] A further exemplary aspect of the invention provides a plurality of valves that are disposed to correspond to individual ones of the containers, such that sensor devices monitor the containers on the exit feed path and produce data representing past performances of each respective valve of the plurality of valves, which is used to determine the period of time that the plurality of valves respectively remain open for subsequent fillings.

[0014] An additional exemplary aspect of the invention includes an entrance feed path that leads the containers to the carrier, and at least one additional sensor positioned adjacent to the entrance feed path to observe measured data about each container while on the entrance feed path. The additional sensor is operative to determine a wide range of features, such as, for example, volumetric capacity of the containers, container type, and container temperature before the containers are disposed on the carrier. It can also be used to detect flaws in the containers which may adversely affect the filling operation. Information pertaining to the volumetric capacity or temperature may be utilized to initially determine the period of time that the valve or respective valves remain open.

[0015] It is also contemplated that an exemplary embodiment of the invention includes a plurality of valves to fill the containers, and an encoder that provides a signal stream that allows correlating the containers to the respective valves, so that historical fill level data and performance characteristics of each valve can be logged and tracked over a period of time. The period of time that the valves are opened for subsequent fillings is accordingly adjusted based on the fill level historical data. The sensor may obtain data from a plurality of containers that were each filled by the corresponding valve to provide historic data, such that a performance trend of the valve is provided to predict future performance of the valve. Further, additional data, besides the level of liquid, may be used to predict and adjust the future performance of the respective valves.

[0016] In accordance with an additional exemplary embodiment of the invention, a method of adjusting an amount of liquid that flows into a plurality of containers is

provided, including transporting the containers by a carrier and flowing liquid into the containers through a filling valve. An amount of liquid that flows into the containers is controlled while the containers are transported by the carrier. The amount of liquid is controlled by regulating a period of time that the filling valve remains open for flow. The containers are conveyed along an exit feed path after the containers have been filled, and a level of liquid in the containers is sensed while the containers are on the exit feed path to produce a signal which represents the level of liquid. Accordingly, the period of time that the valve remains open for subsequent fillings is adjusted based on the signal.

[0017] An additional exemplary embodiment of the invention provides a carrier for transporting containers and means for controlling a period of time that liquid flows into the containers, while the containers are transported by the carrier. An exit feed path is provided which conveys the containers after the containers have been filled. The exit feed path may include the last portion of the rotary travel of the carrier after filling as well as a run-out conveyor or another rotary or linear carrier that transports the just filled container along its path to or through a subsequent machine or material handling operations. Also included is means for sensing a level of liquid in the containers while the containers are on the exit feed path, such that the means for sensing produces a signal which represents the level of liquid. Accordingly, the period of time is adjusted for subsequent fillings based on the signal.

[0018] An exemplary feature of the invention is the elimination of volumetric flow or mass flow control sensors at each individual valve. Such flow or mass control sensors dedicated to each valve are expensive and, in accordance with the present invention, can be replaced by a valve that opens and closes based on a timing recipe, rather than a sensor that actually measures a volumetric fluid amount. This is an economical advantage because flow control sensors are relatively expensive and the more sophisticated mass flow sensors are even more costly. Therefore, the present invention is able to eliminate the flow sensors in favor of another technology which can potentially provide additional functionality and substantial cost savings.

[0019] The integrated sensing and filling system of the present invention may not only replace the basic function of the flow control sensors, but can be implemented to provide other inspections that are also useful. For example, an exemplary embodiment of the sensing system can provide inspection for cap placement, cap integrity, tamper-band integrity, label presence, and similar inspections, as part of its extended functionality.

[0020] An additional feature of the present invention reduces an occurrence of a single anomaly that causes an incorrect valve setting change. This is accomplished by looking at a statistically significant number of measurements before a change is made in a timing recipe or a filling time period. By looking at enough filled bottles to provide a statistically significant sampling, the mean, standard deviation and statistical trends for each valve can be determined with a high confidence level and the system can then correct the timing recipe accordingly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The above aspects and features of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings, in which:

[0022] FIG. 1 is a top view of a liquid filling machine and sensor according to an exemplary embodiment of the invention;

[0023] FIGS. 2a and 2b are cross sections of exemplary valves taken along line A-A of FIG. 1;

[0024] FIG. 3 is a schematic representation of a machine vision sensing configuration, according to an exemplary embodiment;

[0025] FIG. 4 is a schematic representation of a machine vision sensing configuration, according to another exemplary embodiment;

[0026] FIG. 5 is a schematic representation of a machine vision sensing configuration, according to a further embodiment;

[0027] FIG. 6 is perspective view showing a sensor and a plurality of containers according to an exemplary embodiment of the invention;

[0028] FIG. 7 is a flow diagram representing a method according to an exemplary embodiment of the invention; and

[0029] FIG. 8 is a flow diagram representing a further method according to an exemplary embodiment of the invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS OF THE INVENTION

[0030] FIG. 1 is a top view of a filling machine 10 having a rotatable carrier or carousel 12 for transporting containers 14. A wide variety of containers may be used in the present apparatuses and methods, such as glass, plastic, metal, paperboard or the like. For example, the apparatuses and methods may be used to measure liquids or granular solid materials, such as fine chemicals, pharmaceuticals or food-stuffs, or materials comprising solids suspended in liquids. The containers themselves can also vary widely in size and shape and may have the form of, for example, drums, carboys, flasks, cartons, jars, cans, and bottles. However, an exemplary embodiment of the present invention is intended for use with containers containing liquids and, accordingly, the detailed description of the processes hereinafter will mainly be with reference to such bottles of liquid, since the necessary modifications of the apparatus and method for use with other types of containers and contents will be readily apparent to those skilled in the container handling and filling art.

[0031] The incoming containers 14 move on an input path or conveyor 18 and are picked up by the carrier 12 in a traditional manner, such as a feed star wheel. Electrically controllable valves 20 are positioned above the carrier 12 to regulate the flow of liquid into the containers 14 based on a filling recipe and remain with the containers 14 while they are rotated around a center vertical axis in either a clockwise or a counter-clockwise direction by the carrier 12. As used

herein, the term “recipe” may represent a timing configuration use to regulate flow of fluid into the containers 14.

[0032] It will be appreciated that the carrier 12 can rotate in any direction depending on the device’s configuration and manufacturing plant layout considerations. FIGS. 2a and 2b show exemplary valves 20a and 20b which are consistent with the present invention. Valve 20a is used with products that do not include carbonation and do not directly contact the containers 14. Valve 20b is suitable for use with carbonated products and includes a sealing device 21 that contacts the containers 14 and maintains pressure between a nozzle of the valve 20b and the containers 14. The containers 14 are positioned to have their open tops facing up toward the filling valves 20a and 20b, such that the valves 20a and 20b are located above the containers 14 and are axially aligned with the containers 14 for the purpose of filling in a conventional manner.

[0033] The valves 20a and 20b are typically brought into intimate contact with containers 14 or to a position very close to the containers 14 by a rotary cam operated mechanism so that an accurate timing can be provided for a wide range of containers that may be filled by the machine. The valves 20a and 20b fill the containers 14, via a conduit 22 that supplies the product, on the basis of a precisely controlled elapsed time for each filling valve 20a and 20b. Compressed air is introduced through an input 25 and is used to move internal plungers of the valves 20a and 20b to start and stop the flow of the product. The valves 20a and 20b in general may be electrically controlled through solenoid valves, while being air actuated.

[0034] The valves 20 do not necessarily need to be electric valves in order to practice the present invention. However, the valves 20 should be electrically “controllable” in some form to provide a practical application. Alternatively, the valves 20 could be electric or hydraulic servo controlled and may have an infinite amount of fill flow rate adjustment that provides for a wide range of filling rate profiles. The valves 20 could also take the form of an electrically or servo adjusted cam, driving a mechanically operated valve, such that the valves 20 can respond to electrically communicated changes for adjusting the cam timing periods, cam actuation shapes, or the cam durations.

[0035] In an exemplary embodiment, two-position conventional electrical solenoid-operated valves are utilized. Such valves 20 will usually have a high flow position and a low flow position and each position may have its own solenoid operation coil. While being filled, the containers 14 pass through a high flow rate section 23 and a low flow rate section 24. The times that the respective valves 20 are open for high speed filling and low speed filling are adjusted by sensing previous fill levels and utilizing the valves’ 20 respective electronics and software on the basis of each valves’ 20 historical performance, current sensing data, and trending. As will be appreciated, the flow rate could alternatively be such that it continuously increases from its beginning to end.

[0036] An electronic timing device associated with the valve configuration may be used to shift the valve from the high volume flow position to the low volume flow position, such that the high volume flow and low flow volume are maintained for a predetermined amount of time, and can trigger an end to the flow to complete the filling procedure.

There may be a separate elapsed time for the high volume filling section 23 and a separate elapsed time for the low volume section 24. The elapsed time that the valve 20 is opened may only need to be periodically adjusted in accordance with the results of the detected liquid levels. Alternatively, the valve recipe may be defined and controlled on the basis of encoder ticks or precise rotary positioning if this application provides an advantage for a particular implementation of the invention. With such an implementation, the rotational speed (radians per second) of the filler carrier should be monitored and controlled more precisely for satisfactory results.

[0037] When it is detected that a sufficient amount of fluid has been supplied at the high flow rate, the valves 20 are shifted by an electronic control device to a second or slow fill position. The electronic control device could range from a dedicated electronic board that is located near the respective valves 20, for a fast response, to a conventional programmable logic controller (PLC), which has been configured to perform this function, as discussed in more detail below. Various configurations can be utilized including, for example, controlling multiple valves 20 with a single PLC. Careful configuration control should be adhered to so that the PLC based control architecture and software can maintain timing precision and repeatability that will yield satisfactory filling results consistency. This can vary substantially based on the machine design, speed of filling, and the systemic responsiveness.

[0038] The valves 20 may be dual conventional solenoid coils or a double wound coil, for example. Each coil portion of the solenoid is fed an electrical current to actuate the solenoid to each of the valves' two positions. As the valves 20 are electrically shifted to the second position, they throttle flow at the slow pace for a duration around the carousel 12 and, as the containers 14 near their proper fill level, the valves 20 provide the flow at a more precisely controlled slow pace in the low flow rate section 24.

[0039] In an exemplary embodiment, the "on" point to open a valve 20 may be set to start at a precise time while the container is in the high volume flow section 23 and the "off" point may be in the low volume fill section 24. The particular on/off instructions may be calculated by algorithms stored in a computer, which are chosen to optimize the filling times to produce accurate amounts of fluid in the containers 14. The variables used by the algorithms are based on the liquid levels of the filled containers 14 so that subsequent filling amounts can be calibrated.

[0040] After the valves 20 are shut off completely, they will usually retract smoothly by a rotary cam operated mechanism from their intimate filling position with the containers 14. The filled containers 14 will generally exit the filling section and enter a capper or seamer section to have an appropriate type of closure installed, depending on the container style.

[0041] A sensor or camera 28, which is discussed in more detail below, is provided along an exit feed path "B" to form part of a vision based sensing system that captures an image of each container 14 which has exited the carrier 12, to determine a level of liquid in the containers 14, as they move along, or are stopped on, a conveyor 26. It will be appreciated that the exit feed monitored by the camera 28 may include the area B through the latter portion of the rotary

travel of the carrier 12 after filling, as well as the conveyor 26, or other run-out conveyor or another rotary or linear carrier that transports the just filled container along its path to a subsequent machine or material handling operations. The sensor 28 images the containers 14 after they have been filled and have exited the carrier 12 so that subsequent filling times can be adjusted based on the sensed liquid levels. The filling time instructions or recipe for each different filling valve will likely be unique. An additional sensor or camera 30 can also be provided along the input path 18 to observe the containers 14 before being filled with liquid.

[0042] The sensor 28 is operative to correlate an individual container 14 on the output conveyor 26 or the exit feed path B to the valve 20 that provided fluid to that particular container 14. The container 14 can be correlated to its particular filling valve 20 in any known manner. For example, indexing signals may be used with an encoder or the sensor to allow the system to correlate each inspection to the respective filling valve. Also, since the filling valves 20 are assigned a number, as each container 14 passes the sensor 28, its valve number is placed into memory along with the level of liquid in the sensed container 14. Therefore, as each container 14 is imaged by the sensor 28, the valve number is extracted from memory and associated with the liquid level and any other sensory information that has been logged. The vision system including the sensor 28 functions to observe the containers 14 and, thus, learn the performance of each individual valve 20 so as to update the filling recipe periodically.

[0043] The sensor 28, shown in FIG. 1, is disposed just outside the carrier 12, after an exit point 29, but may be placed at any point after which filling is complete. A location may be chosen which minimizes the effects of vibration, turbulence, centrifugal forces, and other forces that may act on the liquid level in the bottle. By having the sensor 28 focused on the fill area of a single bottle it is possible to obtain high levels of resolution combined with a refined illumination to produce a high quality image, such that the system can employ sophisticated algorithms for monitoring each valve's 20 performance.

[0044] FIG. 3 is a schematic diagram of a system consistent with the present invention that incorporates the sensor 28 and a container 14 positioned adjacent thereto. The image of the container 14 acquired by the sensor 28 is stored in a memory of a computer or processor 34 that performs functions, such as internal data calculations and determining a volume of the fluid in the containers 14. The sensor 28 has a field of view which includes a surface 36 of the container's liquid 35 plus a buffer both above and below the nominal fill level which is large enough to account for the variation in fill level that the system may tolerate. Accordingly, the sensor 28 is operative to detect an amount of fluid 35 in the container 14 by detecting the fluid's level 36 and sending the image information via an input signal line 37, in the form of electronic data, to the processor or computer 34 for storage and analysis. The analysis determines the liquid fill level 36 and determines if it is in a normal range of variation that is acceptable. The processor 34 evaluates the sensed level in light of previous readings and mathematically determines the mean and standard deviation of such readings. The processor 34 also calculates the confidence level and an appropriate statistically significant sample size that is needed to provide a sufficient number of liquid level 36

readings, before making a change to the timing recipe for the particular valve 20 corresponding to the sampled readings. Thereafter, the processor 34 provides an output signal along data line 38 to a PLC 40 that compiles a calculated time adjustment 41 for the valve 20. As shown, three valves 20, 20' and 20" are illustrated for the purpose of this description. However, a typical filling machine would include many more valves. In an exemplary embodiment, the PLC 40 then sends an "on" or "off" electric signal 43, 43' and 43" to air solenoid valve 42, 42' and 42", which are respectively plumbed to the filling valves 20, 20' and 20" responsible for filling the sensed container 14, 14' and 14" to send compressed air into the appropriate valves 20, 20' and 20" via the input lines 25, 25' and 25" to fill subsequent containers with an updated time recipe 41 corresponding to the particular valves 20, 20' and 20". Depending on the processor's 34 configuration, it may include a display for graphically illustrating the obtained data and for adjusting fill level settings graphically. It will also be appreciated that the processor 34 and the PLC 40 could be incorporated into one device which performs the desired procedure.

[0045] By repeatedly measuring the fluid levels 36 of the containers 14, 14' and 14" that are sequentially filled by the same valve, the historic attributes of the valves 20, 20' and 20" can be obtained to provide trend data. For example, it can be observed whether a particular valve stays open too long or not long enough. It can also observe the repeatability of each valve by way of the resultant filling consistency and standard deviation from the mean. It can then be determined whether a flow adjustment needs to be made in the high flow section 23 or the low flow section 24.

[0046] Based on the measured results of the liquid levels 36, the processor 34 and the PLC 40 can provide an instruction to adjust the elapsed time that the valves 20 remain open during the filling procedure. The processor 34 maintains the historical database of liquid levels 36 corresponding to the performance of each valve 20, 20' and 20". Because the present elapsed filling times are known, in addition to the liquid levels produced by the present filling times, the system can make accurate recommendations to change the elapsed times that the valves 20, 20' and 20" remain open, so as to continuously improve the accuracy of the filling procedure. For example, if a particular valve is shown to be over filling or under filling based on mathematical statistics including, for example, mean and standard deviation calculations, for a certain sampling of containers 14, 14' and 14", the valve opening time may be appropriately shortened or lengthened depending on the desired corrections. An exemplary sampling amount may include between 40-60 containers 14, 14' and 14" that are filled by the same valve, and the amount of valve timing change may be a factor of milliseconds.

[0047] The sensing or imaging of the liquid level may be implemented with a range of technologies, including non-contact technologies, for example, but not limited to, radio frequency sensors, ultrasonic sensors, electro optical sensors, x-ray sensors, laser scanners, infra-red sensors, capacitive sensors and the like. The particular application, types of material out of which the container 14 is manufactured, and the cost practicality of the implementation may dictate which one is most applicable for a particular filling application.

[0048] In an exemplary embodiment, the imaging system including the camera or sensor 28 could utilize a machine vision configuration with a strobed backlighting source. The camera 28 would snap an image when a part detection sensor indicates the presence of the filled container 14 at a particular position appropriate for inspection. An encoder or resolver, operative from an area near the conveyor 26 or exit feed path B, could then indicate the progress of the container 14 until it is in an appropriate position for imaging. At that point, an electronic subsystem or computer 34 would prepare the camera 28 to capture the image, while a strobed backlighting is triggered to provide an illumination pulse which freezes the movement of the container 14 for an instant while the image is taken. An alternative to the strobing of the backlight is to use a continuously "on" light source and electronically shutter the camera at a high speed to provide a near equivalent image capture scheme. It is also possible to use a technique called smeared imaging which can have certain advantages as well as drawbacks. With this technique, the camera shutter is purposely held open when the container is in the field of view. The resultant image is a smear of the vertical contrast as integrated over the time that the container is traveling horizontally through the image. If the smear window is chosen carefully, for some applications, this provides a sort of averaging that may be advantageous in reducing the amount of image processing requirement. The challenge with this technique is that contrast may be too suppressed for robustness in the inspection.

[0049] A backlit image may also be used which provides a combination image that is part silhouette and partly a "light transmission image" in which the liquid absorbs more light than the unfilled top portion of the container 14. The "fill line" is then clearly visible and is further amplified and more visible because of the refraction of the light caused by the meniscus at the interface of the liquid with the glass with the air space above it.

[0050] The captured image is read out of the camera 28 and transmitted into image processor electronics of the computer 34. The image is then analyzed using algorithms, which may be particularly designed into the software of the computer 34, for the purpose of determining the fill level 36 from the image data. For example, the image processing algorithm in the computer can compare the contrast as vertical lines that are traced from the region of the image that should definitely be liquid 35 up through the transitional zone where the liquid interfaces with the air and then into the air space. By doing this in the desired number of locations in the measurement region, it is reasonable to determine a numerical average that is representative of the liquid level 36. Upon determination of the fill level 36, further algorithms are used that are designed to analyze how the currently measured fill level 36 compares to fill levels 36 of containers 14 that have been measured previously to provide historical data and to derive various aspects of trending data. The trending data can be used to predict maintenance schedules and impending failure modes. For example, the system may be able to ascertain that a particular valve 20 is performing in an increasingly erratic way. This may indicate a sticking solenoid or valve poppet. The historical data is then used to update the respective filling valve actuation times to obtain optimum filling results.

[0051] Additional aspects can be implemented to improve the accuracy of fluid level readings under differing condi-

tions. For example, it is possible to use different wavelengths of light, whether in the visible or the non-visible portions of the spectrum, to provide a better contrast and, therefore, better measurements. U.S. Pat. No. 5,365,084 teaches the advantages of wavelength specific illumination systems that can use different combinations and permutations of wavelengths from differing angles to highlight and increase contrast as desired, the disclosure of which is hereby incorporated, in its entirety, by reference. It may be advantageous under some applications to use a wavelength specific illumination system to help improve the measurements that are pertinent to proper filling valve optimization. For example, some darker colored bottles, like amber, may be difficult to illuminate with normal visible backlight sources, but are readily penetrated with near infrared illumination. At the same time, a green bottle is penetrated nearly as well as an amber bottle and its grey scale image does not show a substantially higher contrast than the amber bottle. By using a combination of light wavelengths, it is possible to not only better detect the correct fill level, but also to detect if an incorrect color bottle has been filled.

[0052] It is also possible to use a similar technique with chosen wavelengths to analyze foam differently than a dense liquid product. For example, it may be determined empirically that 25 mm of dense foam equals 10 mm of liquid, while 25 mm of low density foam may only be the equivalent 4 mm of the same liquid. Such a correlation may be made by reference to a look-up table.

[0053] The filling time periods for each valve may be even further optimized beyond an initial timing determination. For example, the additional camera or input sensor 30, shown in FIG. 1, can also detect a container that is larger or smaller in volume than a nominal specification, such that the actuation time of the corresponding valve 20 can be adjusted proactively to obtain a correct fill amount. As will be appreciated, it sometimes may be appropriate to fill the containers by delivering a predetermined volumetric amount or it may be appropriate to fill to a measured fill line. The actual dimensions of the container 14 can directly affect both of these approaches. Therefore, the use of the input sensor 30 for inspecting incoming containers can be useful in either situation. These and other features herein described can contribute to an implementation of an adaptive, self learning, and "smart" filling machine.

[0054] In further accordance with an exemplary embodiment of the present invention, information sensed by the additional sensor pertaining to container type, size, model, design, or style can be used to trigger access to a database that has historical setting filling recipes for each respective valve 20 for filling that specific container. Such a pre-filling, or ingoing sensory system, using the input sensor 30 can be useful in setting up the system automatically, with little or no human operator attention.

[0055] The input sensor 30 may also be operative to identify incorrect containers so that a particular valve in the filling system is held closed and the incorrect container is not filled at all, or so that it is rejected after filling. Thus, an incorrect container, whether filled or empty, can be subsequently rejected from the stream of containers as a proactive measure.

[0056] The processor 34 may include a programmable logic controller (PLC) or they may be separate devices, as

shown in FIG. 3, with each having a central processing unit (CPU) and an input/output interface. In the exemplary embodiment of FIG. 3, the processor 34 calculates and controls the timing recipes and sends them to the PLC 40 via communications link for storage and execution. The input/output interfaces facilitate communications between the processor 34, the sensors (i.e., input), the PLC 40 and the valves 20 (i.e., outputs).

[0057] In operation, the processor 34 reads input data from the sensor 28 and then "executes" or performs a control program using the algorithms for optimizing the valves' 20, 20' and 20" timing. Based on the algorithms, the PLC 40 updates the elapsed time instructions for the valves 20, 20' and 20" via the output interfaces.

[0058] As an alternative to using a PLC 40 for the valve firing, electronic boards 39, 39' and 39" connected to the data line 38 can be dedicated to a number of valves 20, 20' and 20", as shown in FIG. 4. The shown configuration includes one electronic board per valve, but multiple valves could be controlled by a single electronic board. Each such electronic board 39, 39' and 39" would be responsible for executing the timed on and off sequence for both slow and fast coils of the valves 20, 20' and 20" and would perform this repetitive duty for each of the valves 20, 20' and 20" that it is dedicated to controlling. The valves 20, 20' and 20" could receive a trigger signal from a photocell or other similar devices known in the art indicating when each filling valve 20, 20' and 20" has passed a certain point in the rotation of the carousel 12. The electronic boards 39, 39' and 39" would then fire or execute a time recipe, to the respective valves 20, 20' and 20", which is held in its non-volatile memory. Periodically, as needed, each such electronic board 39, 39' and 39" could send new triggering recipes for each of its valves 20, 20' and 20" based on the fill level sensing measurements. Such dedicated electronic boards 39, 39' and 39" would typically be capable of accurately and repeatedly executing a precise firing timing that would facilitate optimization of the filling. FIG. 5 represents an exemplary embodiment using the PLC 40 and the electronic board 39 together. The PLC 40 and electronic board 39 act together to provide a signal for controlling the valve 20. For the sake of simplicity, only one electronic board 39 is shown. However, in use, multiple electronic boards 39 could be used to control multiple valves 20.

[0059] In general, it may not be necessary to communicate to each valve 20 for each individual filling procedure because the control electronics of the valves 20 should accurately provide repeatable elapsed times for the respective valves 20. The system will periodically update the elapsed times as needed to maintain accurate fluid levels though multiple fillings over a period of time. As will be appreciated, there are variances in the responsiveness and performance between different valves 20. However, the most frequently changing component of the valve's 20 variable attributes may be the elapsed filling times, which are sampled and analyzed to optimize fill levels.

[0060] A situation that should be avoided when sampling and adjusting the valves 20 is known as valve setting "hunting". "Hunting or oscillation" phenomenon is understood in many fields, such as classical PID (Proportional-Integral-Derivative Control) theory and/or mathematical statistical sampling theory. It is a circumstance whereby an

adjustment is made, which is not correct, followed by a further adjustment, which is also not correct. In effect, the system goes into a loop of corrections, never finding a stabilized adjustment. By way of example, suppose an adjustment appears to be required to the valve “on-time,” based on previously gathered measurements, but the timing adjustment recommended by the system is based on one or more inaccurate measurements. Because the recommended change is based on inaccurate measurements, the change is based on the wrong input. The valve, however, faithfully executes its filling time with the new lengthened or shortened setting. Subsequently, as new measurements of the fill level are made, it is again recognized that the fill level has been improperly adjusted. A new adjustment is then required which may also be based on an inaccurate measurement and may similarly assign an improper value. As this type of flawed adjusting continues, it is possible to create a continual “hunting” or oscillation situation which does not promote optimized valve settings for the filling machine. Therefore, a statistically significant change should be reliably detected by way of the chosen statistically significant sample size before a change in the valve triggering timing is warranted. Thus, although it is possible to practice this invention using single measurements of the fill level, it is not recommended for most optimized results.

[0061] FIG. 6 is a perspective view of the sensor 28 positioned approximate to the containers 14 so as to analyze the fluid level of multiple containers 14 at one time. The operation of the sensor 28 and computer 34 in this embodiment is similar to that of FIGS. 3-5, except for data of multiple containers is obtained at one time. It will be appreciated that the embodiments of FIGS. 3-5 may similarly sense multiple containers simultaneously. The sensor 28 can work in conjunction with a backlight 44, which may be strobed and extends the length of an area encompassing the sensed containers 14. The data obtained by the sensor 28 is then transferred to the computer 34 for analysis and, in a manner similar to that described above, the derived information is manipulated to provide fill time instructions to the respective filling valves 20.

[0062] In a further embodiment, dimensional measurements of the containers 14 are obtained by the additional sensor or camera 30, shown in FIG. 1, prior to the filling operation. From the measured dimensions, the volumetric capacity of individual containers 14 could be calculated by the computer 34 where further intelligence is applied to modulate the filling recipes accordingly. The volumetric calculation can be used to point to a particular filling recipe, from a selection included in a look-up table, provided in the valve's electronics or the computer 34, for example. This process can be more efficient than transmitting a completely new filling recipe for each bottle and could result in more precise filling levels for certain types of bottles. For example, it is known that certain types of bottles have a much greater level of manufacturing variation than other types, such that this additional feature could be useful to extend the basic functionality of the smart, vision-based filling system.

[0063] It is contemplated that there are many other aspects that the system can learn and incorporate in the performance history for each valve besides the filling times. Accordingly, to affect a reliable and consistent filling in an exemplary embodiment of the invention, it is beneficial that other

parameters of the filling machine, besides the filling times, be held to tightly controlled levels. For example, the pressure of the filling liquid should be consistent so that it does not create another variable that affects the system.

[0064] Therefore, additional aspects of learning and acquiring feedback may be utilized. A number of data aspects could be used to more precisely characterize each valve's performance over time. In an exemplary embodiment, the computer 34 could become a central repository for sensory data input which would relate to overall filling performance. For example, additional data such as temperature, pressure, valve current signature, flow rates at other points in the machine, and many other pieces of data could be incorporated into the historical performance chart. One could, therefore, use this information to mathematically project performance in the future and could incorporate the information into a learning neural network which would predict performance, enhance filling repeatability, and predict machine maintenance as well.

[0065] Contact sensing technology may be used which weighs the filled container 14 to provide historical data. For example, the weight of a currently measured filled container 14 could be compared with past measurements to provide historical data used to evaluate and determine optimum filling valve actuation durations and settings.

[0066] Moreover, the containers 14 may be sensed from multiple different directions and angles to get different views. This sensing may apply to the “pre-look” (unfilled container) which is carried out by the camera or sensor 30 as well as the “post-look” (filled container) which may be carried out by the camera or sensor 28. This feature is useful for prospectively determining the exact size (volume) of each bottle that will be or has been filled. Various types of sensor technologies could be used for performing this procedure such as, for example, the mass sensing technology described in U.S. Pat. No. 6,872,895, which is hereby incorporated in its entirety by reference.

[0067] FIG. 7 represents a flow chart of an exemplary method of the invention. The process begins with transporting the containers 14 by the carrier 12 (S100). The liquid is then dispensed into the containers 14 through the filling valve 20 (S110), such that the flow is controlled by manipulating the precise amount of time that each filling valve 20 remains open (S120). The containers 14 are then conveyed along the exit feed path B after they have exited the carrier 12 (S130), such that the level 36 of liquid in the containers 14 is detected to produce a signal (S140). After the level of liquid 36 is sensed, data is gathered and, when needed, a period of time that the valve remains open for subsequent fillings is adjusted (S150).

[0068] The flow of liquid into a plurality of the containers 14 is controlled using separate filling valves 20, such that data is collected to represent the level of liquid 36 provided by the separate valves 20. Based on the data, the period of time that each of the separate valves 20 remains open for subsequent fillings can be adjusted. It will be appreciated that the levels of liquid in a single container or, more preferably, but not necessarily, multiple containers, may be detected before making an adjustment, even when the levels of liquid are not consistent between the multiple containers, as long as the detected levels are within an acceptable range. By providing the entrance feed path 18 to the carrier 12, the

containers 14 can be preliminarily observed by the input sensor 30 to determine the volumetric capacity of the containers before the containers are disposed on the carrier.

[0069] FIG. 8 represents a method according to a further exemplary embodiment that incorporates pre-fill sensing, using the camera or sensor 30 shown in FIG. 1, for example. Operations of FIG. 8 are similar to those in of FIG. 7, while further including an operation which detects physical attributes and/or specifications of the containers using a pre-fill sensor or camera (S102). After the containers are viewed by the pre-fill sensor or camera, access is made to a database to obtain stored filling recipe information corresponding to the detected container (S104). Therefore, pre-determined elapsed times for the valves 20 can be initially used, which may then be adjusted based on the data gathered by the sensor 28, and/or sensor 30, or provided by other sensory inputs.

[0070] The method also contemplates utilizing all other additional aspects of the invention discussed above, including the aspects of learning and acquiring feedback. For example, the method may include using a number of data aspects to more precisely characterize each valve's performance over time and use the computer 34 as the central repository for sensory data input that would relate to overall filling performance.

[0071] Inaccuracy in the sensing or measuring of the liquid may be inevitable because of waves, ripples, turbulence, foam, bubbles, sloshing and other disturbances that occur at the liquid to air interface at the top of the liquid, which has just been filled, into the container 14. To improve such disturbances, a length of the output conveyor 26 may be provided to allow for some settling time before the liquid is measured by the sensor 28.

[0072] Another contributor to inaccurate measurements of a fill level includes a range of normal process variations in the containers 14 themselves. For example, the container 14 can have bubbles or blisters in a sidewall through which the sensor 26 must view. Because of the nature of glass or plastic containers, this causes an anomalous refraction or reflection that can change the image from which the measurement is made. Many other similarly detrimental anomalies, such as ridges or partially choked necks can cause inaccurate measurements. Therefore, the various types of sensors and cameras described above, along with an appropriate sampling amount, should be taken into consideration based on the particular filling application.

[0073] The previous description of the exemplary embodiments is provided to enable a person skilled in the art to make and use the present invention. Moreover, various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles and specific examples defined herein may be applied to other embodiments without the use of inventive faculty. Therefore, the present invention is not intended to be limited to the embodiments described herein, but is to be accorded the widest scope as defined by the limitations of the claims and equivalents thereof.

What is claimed is:

1. A filling apparatus, said filling apparatus comprising:
a carrier for transporting containers;

- a plurality of electrically controllable valves, each of which is opened for a period of time to fill a first group of said containers respectively with a liquid, while said containers are transported by said carrier;

- an exit feed path which conveys said containers after said containers have been filled; and

- at least one sensor which detects a level of liquid in said containers, while said containers are on said exit feed path, such that said sensor produces respective signals which represent the level of liquid in each said first group of containers,

wherein said plurality of electrically controllable valves are configured so that the period of time that said plurality of electrically controllable valves are individually opened is adjusted for subsequent fillings based on said signals corresponding to said first group of said containers.

2. The filling apparatus of claim 1, wherein said electrically controllable valves are electric servo valves which allow control that provides more than two filling speeds.

3. The filling apparatus of claim 1, wherein the plurality of valves are provided to correspond to individual ones of said containers, such that said sensor monitors said containers on said exit feed path and produces data representing past performances of each of the plurality of said valves, which is used to determine individually the period of time that the plurality of valves each remain open for the subsequent fillings.

4. The filling apparatus of claim 1, wherein said at least one sensor is a stationary camera and a respective illumination source positioned to observe said containers in said exit feed path, and said exit feed path is a path that the containers, which have been filled, follow after filling and after the valve has been shut off.

5. The filling apparatus of claim 1, wherein said sensor communicates with a processor which receives said signals and controls said period of time that each of said plurality of electrically controllable valves are kept open.

6. The apparatus according to claim 1, further comprising an entrance feed path that leads said containers to said carrier, and at least one auxiliary sensor positioned adjacent to said entrance feed path to observe said containers while on said entrance feed path, said auxiliary sensor is operative to determine a volumetric capacity of said containers before said containers are disposed on said carrier for filling.

7. The apparatus of claim 6, wherein information pertaining to said volumetric capacity is utilized to initially determine the period of time individually that each of said electrically controllable valves remain open.

8. The filling apparatus of claim 1, wherein said electrically controllable valves provide a period of high flow and a period of low flow, such that at least one of said period of said high flow and said period of low flow is adjusted based on said signals.

9. The filling apparatus of claim 4, wherein the illumination source is comprised of solid state devices and is equipped to produce more than one wavelength.

10. The filling apparatus of claim 1, wherein the level of liquid in multiple containers, filled by one of said electrically controllable valves, is detected by said sensor before adjusting said period of time that said one of said electrically controllable valves is opened, even when the levels of liquid are not consistent between said multiple containers.

11. The filling apparatus of claim 1, further comprising:
one of an encoding device and a detection sensor that facilitates associating the containers respectively to said valves, so that fill level data of each of said valves can be tracked over a period of time,
wherein said period of time that said valves are opened for the subsequent fillings, is adjusted based on said tracked fill level data.
12. The filling apparatus of claim 1, wherein said sensor obtains data from said plurality of containers to provide historic data for said valves, such that a performance trend of each of said valves is provided to predict future performance of said valves.
13. The filling apparatus of claim 5, wherein said processor utilizes an algorithm to determine whether said electrically controllable valves should be adjusted.
14. The filling apparatus of claim 5, wherein said processor utilizes an algorithm to determine at least one of how, and how much to adjust the period of time that said valves are opened.
15. The filling apparatus of claim 1, further including a timing device which regulates said period of time that each of said valves remain open so as to fill a predetermined amount of said liquid into said containers,
said timing device being capable of being periodically updated to new regulation times based on signals from said at least one sensor.
16. The filling apparatus of claim 12, wherein additional data besides the level of liquid is used to predict the future performance of each of said respective valves.
17. The filling apparatus of claim 16, wherein said additional data includes at least one of temperature of the liquid, pressure of the liquid, ambient temperature, container mass, container shape, container wall thicknesses, container volume, liquid flow rates, machine speed, and valve current.
18. The filling apparatus of claim 1, wherein said carrier is rotatable.
19. The filling apparatus of claim 6, wherein said at least one auxiliary sensor is an electronic camera.
20. The filling apparatus of claim 1, wherein said at least one sensor senses levels of liquid in a plurality of said containers simultaneously.
21. A method of adjusting an amount of liquid that flows into a plurality of containers, the method comprising:
transporting the containers by a carrier;
flowing liquid respectively through a plurality of filling valves into the containers;
controlling an amount of liquid that flows into the containers while the containers are transported by the carrier, the amount of liquid being controlled by electrically opening the plurality of filling valves for a predetermined period of time;
conveying the containers along an exit feed path after the containers have been filled;
sensing a level of liquid in the containers while the containers are on the exit feed path to produce signals which represent the level of liquid in the containers, respectively; and
adjusting the predetermined period of time that each of the plurality of filling valves remain open for subsequent fillings based on the signals.
22. The filling method of claim 21, further comprising:
obtaining information pertaining to the level of liquid in a first group of the containers, filled by a first of said plurality of filling valves, to control the period of time that liquid flows into containers that are to be filled subsequently; and
obtaining information pertaining to the level of liquid in a second group of the containers, filled by a second of said plurality of said filling valves, to control a period of time that liquid flows into containers that are to be filled subsequently by the second filling valve.
23. The filling method of claim 21, further comprising collecting data which separately represents the level of liquid provided by each of the separate valves; and
determining the period of time that each of the valves respectively remain open for subsequent fillings based on the data.
24. The filling method of claim 21, further comprising providing at least one stationary electronic camera to perform said sensing.
25. The filling method of claim 21, further comprising providing a processor to receive the signals and control the period of time that the liquid flows into each of the containers.
26. The method of claim 21, further comprising:
providing an entrance feed path that leads the containers to the carrier; and
observing the containers while on the entrance feed path to determine a volumetric capacity of the containers before the containers are filled.
27. The method of claim 26, further comprising initially determining the period of time that the liquid flows into the containers respectively based on at least one of the volumetric capacity and historical data of the filling valves.
28. The method of claim 21, further comprising providing a period of high flow of the liquid into the containers and providing a period of low flow of the liquid into the containers, and adjusting the period of the low flow based on the signals.
29. The method of claim 21, further comprising providing a period of high flow of the liquid into the containers and providing a period of low flow of the liquid into the containers, and adjusting the period of the high flow based on the signal.
30. The method of claim 21, further comprising detecting the levels of liquid in multiple containers filled by a corresponding one of the plurality of valves before adjusting the period of time that the corresponding valve remains open, even when the levels of liquid are not consistent between the multiple containers.
31. The method of claim 23, further comprising:
correlating the containers to the valves which respectively provided the flow of the liquid into the containers,
tracking historical data pertaining to the level of liquid in the containers over a period of time, and

as required, adjusting the time that each of said plurality of valves remains open based on the historical data which is tracked.

32. The method of claim 31, further comprising predicting future flow rates of the liquid through each of the plurality of valves based on the historical sensor data which is tracked.

33. The method of claim 25, further comprising utilizing an algorithm to determine whether the period of time that each of the plurality of valves stays open should be adjusted for subsequent fillings.

34. The method of claim 25, further comprising utilizing an algorithm to determine how much to adjust the period of time that each of the plurality of valves remains open.

35. The method of claim 21, further comprising obtaining additional data, besides the liquid level, to predict when and how much to adjust the period of time respectively that the plurality of valves remain open for subsequent fillings.

36. The method of claim 35, wherein the additional data includes at least one of temperature of the liquid, pressure of the liquid, valve current signature, ambient temperature, container temperature, container mass, container shape, container wall thickness, container volume, liquid flow rates, machine speed, and fill reservoir levels.

37. The method of claim 21, wherein the containers are rotatably transported by the carrier.

38. The method of claim 21, further comprising sensing the levels of liquid in more than one of said plurality of containers substantially simultaneously.

39. A filling apparatus, said filling apparatus comprising:
a carrier for transporting containers;

means for electrically controlling a period of time that liquid flows into said containers, while said containers are transported by said carrier;

an exit feed path which conveys said containers after said containers have been filled; and

means for sensing a level of liquid in said containers while said containers are on said exit feed path, such that said means for sensing produces a signal which represents said level of liquid,

wherein said period of time is adjusted for subsequent fillings based on said signal.

40. The filling apparatus of claim 39, wherein information pertaining to said level of liquid in a first group of said containers is obtained by said means for sensing to electrically adjust the period of time that liquid flows into said containers, and

wherein information pertaining to said level of liquid in a second group of said containers is obtained, said second group of containers being filled by a second means for electrically controlling flow, and is used to adjust a period of time that liquid flows into said second group of containers.

41. The filling apparatus of claim 39, wherein said means for sensing communicates with a processor which receives said signal and controls said period of time for subsequent fillings.

42. The apparatus according to claim 39, further comprising an entrance feed path that leads said containers to said carrier, and a second means for sensing positioned adjacent to said entrance feed path to observe said containers while on said entrance feed path, said second means for sensing is operative to determine a volumetric capacity of said containers before said containers are filled to determine an initial period of time that liquid is to flow into said containers.

43. The filling apparatus of claim 39, wherein said level of liquid in multiple containers is detected by said means for sensing before adjusting said period that liquid flows into said containers, even when the levels of liquid are not consistent between said multiple containers.

44. The filling apparatus of claim 39, wherein said means for sensing obtains data from a plurality of containers that were each filled by said means for controlling to provide historic data, such that a performance trend of said means for controlling is monitored and used to predict future performance of said means for controlling.

45. The filling apparatus of claim 1, wherein the sensor detects the level of liquid in said containers by determining respective weights of said containers, which are filled.

46. The filling method of claim 21, wherein the sensing comprises determining respective weights of said containers, which are filled.

47. The filling apparatus of claim 39, wherein said means for sensing senses the level of liquid in said containers by determining respective weights of said containers, which are filled.

48. The filling apparatus of claim 2, wherein said servo valves allow for an adjustment of a filling speed profile during a filling period.

49. The filling apparatus of claim 1, wherein a processor is provided with a memory that includes an algorithm using at least mathematical statistics including mean and standard deviation calculations to determine when and how much to adjust the timing for each of the plurality of valves, and to measure a sample size for estimating the reliability of a sensor, which performs said sensing.

50. The method of claim 33, wherein the algorithm uses mathematical statistics including at least one of mean and standard deviation calculations to determine when and how much to adjust the timing for each of the plurality of valves, and a calculated sample size for estimating the reliability of a measuring sensor, which performs said sensing.

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