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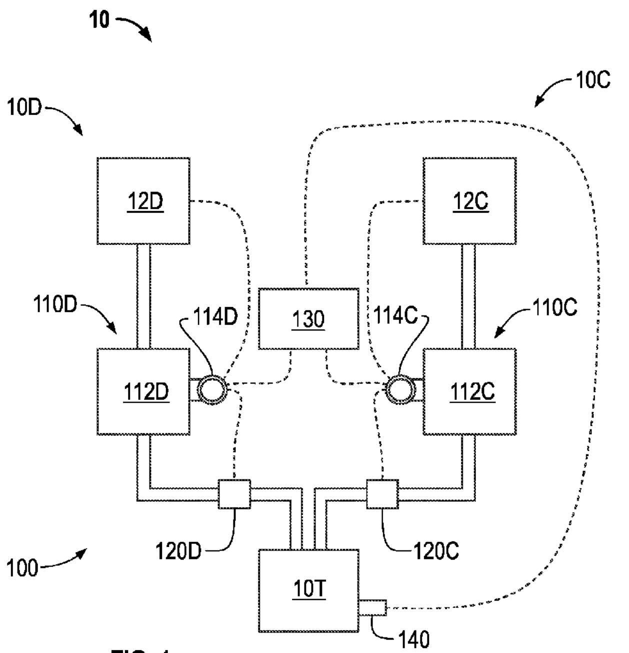


FIG. 1

(57) **Abstract:** A method of two-source flow control for batch processing is provided. The method includes flowing a concentrate and a dilutant into a mixing tank, measuring a flow rate of the concentrate and continuously accumulating the measured flow rate of the concentrate, and measuring a flow rate of the dilutant and continuously accumulating the measured flow rate of the dilutant. The method also includes at least one of discontinuing the flow of the concentrate when the accumulated measured flow rate of the concentrate is equal to a desired total amount of concentrate, and discontinuing the flow of the dilutant when the accumulated measured flow rate of the dilutant is equal to a desired total amount of dilutant.

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# TWO-SOURCE FLOW CONTROL FOR BATCH PROCESSING

## TECHNICAL FIELD

The embodiments described below relate to batch processing, more particularly, to two-source flow control for batch processing.

## BACKGROUND

Dilution of concentrates is used in many different processes to obtain a particular concentration suitable for specific applications. For example, dilution is used in cutting of barrel-strength spirits to bottle-strength in distilling, formulation of buffers in life sciences, and the dilution of caustic soda in chemical or clean-in-place applications. Dilution of concentrates tend to be pervasive across industrial applications due to the efficiencies of transporting raw ingredients in their concentrated form (and hence the need to dilute during production). More specifically, concentrates are more efficient use of space, supply chain by allowing for a single source of a substance that is subsequently dilute near the consumption of a particular concentration of a solution, etc.

Typically, industrial dilution processes involve one inlet measurement of dilutant (water) batched into a mixing tank which contains a previously allocated amount of concentrate. These components are usually measured with a scale on a loading cell, and hence there is a need to add components one at a time. Typically, the concentrate is dosed into the mixing tank first with an approximate, manual method. After the concentrate is weighed, the dilutant amount needed for a target concentration is calculated and then subsequently added to the mixing tank via a manual method. This manual procedure is time consuming, prone to human error and introduces the potential for costly rework if ingredients are dosed incorrectly by overshoot or undershoot.

While full-fledged blending skids exist today for the purposes of automating the manual mixing described above, they are complex systems which require high capital investment and heavy overhead costs (maintenance, training, skid footprint, etc.). A fully automated mixing may be at a fraction of the cost and complexity of traditional blending skid systems. Accordingly, there is a need for two-source flow control for batch processing.

SUMMARY

A method of two-source flow control for batch processing is provided. According to an embodiment, the method comprises flowing at least one of a concentrate and a dilutant into a mixing tank, measuring and continuously accumulating a flow rate of at least one of the concentrate, the dilutant, and a concentrate-dilutant mixture, and discontinuing the flow of the at least one of the concentrate, the dilutant, and the concentrate-dilutant mixture when the accumulated flow rate is equal to a desired total amount.

A flow meter system for two-source flow control for batch processing is provided. According to an embodiment, the flow meter system comprises one of a concentrate flow meter configured to measure a flow rate of a concentrate and a dilutant flow meter configured to measure a flow rate of a dilutant and a concentrate-dilutant flow meter configured to measure at least one of the flow rate of the concentrate, the flow rate of the dilutant, and a flow rate of the concentrate-dilutant mixture. The flow meter system further comprises a system computer communicatively coupled to the one of the concentrate flow meter and the dilutant flow meter and the concentrate-dilutant flow meter, wherein at least one of the system computer and the one of the concentrate flow meter and the dilutant flow meter and the concentrate-dilutant flow meter is configured to execute the foregoing method.

A system for two-source flow control for batch processing is provided. According to an embodiment, the system comprises a mixing tank and the flow meter system according to the foregoing fluidly coupled to the mixing tank.

ASPECTS

According to an aspect, a method of two-source flow control for batch processing comprises flowing at least one of a concentrate and a dilutant into a mixing tank, measuring and continuously accumulating a flow rate of at least one of the concentrate, the dilutant, and a concentrate-dilutant mixture, and discontinuing the flow of the at least one of the concentrate, the dilutant, and the concentrate-dilutant mixture when the accumulated flow rate is equal to a desired total amount.

Preferably, discontinuing the flow when the accumulated flow rate is equal to the desired total amount comprises at least one of discontinuing the flow of the concentrate when the accumulated measured flow rate of the concentrate is equal to a desired total amount of concentrate, discontinuing the flow of the dilutant when the accumulated measured flow rate of the dilutant is equal to a desired total amount of dilutant, and discontinuing the flow of the concentrate-dilutant mixture when the accumulated flow rate of the concentrate-dilutant mixture is equal to a desired total amount of concentrate-dilutant mixture.

Preferably, the flow rate of the concentrate is measured by one of a concentrate flow meter and a concentrate-dilutant flow meter, the flow rate of the dilutant is measured by one of a dilutant flow meter and the concentrate-dilutant flow meter, and the flow rate of the concentrate-dilutant mixture is measured by the concentrate-dilutant flow meter.

Preferably, flowing the concentrate and the dilutant into the mixing tank comprises one of substantially synchronously flowing the concentrate and the dilutant into the mixing tank, and substantially asynchronously flowing the concentrate and the dilutant into the mixing tank.

Preferably, substantially synchronously flowing the concentrate and the dilutant into the mixing tank comprises mixing the concentrate and the dilutant and flowing the concentrate-dilutant mixture into the mixing tank.

Preferably, continuously accumulating the measured flow rate comprises continuously accumulating with respect to time the measured flow rate.

Preferably, the method further comprises obtaining the desired total amount, and continuously comparing the desired total amount with the accumulated flow rate.

Preferably, the desired total amount is based on a target final concentration and a target final amount of the concentrate-dilutant mixture.

Preferably, the desired total amount being based on the target final concentration and the target final amount of the concentrate-dilutant mixture comprises:

$$T_c = T_m \times \frac{C_t}{C_c}; \text{ and}$$

$$T_d = T_m - T_c;$$

where:

$T_c$= total amount of concentrate;

$T_d$= total amount of dilutant;

$T_m$= target amount of concentrate-dilutant mixture;

$C_t$= target final concentration; and

$C_c$= concentration of raw concentrate.

Preferably, the method further comprises measuring a concentration of the concentrate-dilutant mixture in the mixing tank, and comparing the measured concentration with the target final concentration of the concentrate-dilutant mixture.

Preferably, the method further comprises adding concentrate to the concentrate-dilutant mixture in the mixing tank if the measured concentration is less than the target final concentration.

Preferably, an amount of concentrate added to the concentrate-dilutant mixture in the mixing tank is determined according to the following relationship:

$$T_c = \frac{(C_t T_m - C_c T_{ci})}{C_c - C_t};$$

$T_c$ =amount of concentrate to be added for correction;

$T_{ci}$= initial amount of raw concentrate used for an uncorrected mixture;

$C_t$= correct (original target) concentration;

$T_m$= amount of uncorrected concentrate-dilutant mixture; and

$C_c$= concentration of raw concentrate.

Preferably, the method further comprises adding dilutant to the concentrate-dilutant mixture in the mixing tank if the measured concentration is greater than the target final concentration.

Preferably, the amount of dilutant added to the mixture of the concentrate and the dilutant is determined using the following relationship:

$$T_d = T_m \left(\frac{C_m}{C_t} - 1\right);$$

where:

$T_d$ = amount of dilutant to be added for correction;

$C_m$ = concentration of uncorrected concentrate-dilutant mixture;

$C_t$ = correct (original target) concentration; and

$T_m$= amount of uncorrected concentrate-dilutant mixture.

According to an aspect, a flow meter system for two-source flow control for batch processing, the flow meter system comprises one of a concentrate flow meter configured to measure a flow rate of a concentrate and a dilutant flow meter configured to measure a flow rate of a dilutant and a concentrate-dilutant flow meter configured to measure at least one of the flow rate of the concentrate, the flow rate of the dilutant, and a flow rate of the concentrate-dilutant mixture. The flow meter system further comprises a system computer communicatively coupled to the one of the concentrate flow meter and the dilutant flow meter and the concentrate-dilutant flow meter, wherein at least one of the system computer and the one of the concentrate flow meter and the dilutant flow meter and the concentrate-dilutant flow meter is configured to execute the foregoing method.

Preferably, at least one of the concentrate flow meter, the dilutant flow meter, and the concentrate-dilutant flow meter being configured to execute the foregoing method comprises a meter electronics configured to execute the foregoing method.

According to an aspect, a system for two-source flow control for batch processing comprises a mixing tank and the flow meter system according to the foregoing fluidly coupled to the mixing tank.

Preferably, the system further comprises a concentrate supply and a dilutant supply fluidly coupled to the flow meter system.

## BRIEF DESCRIPTION OF THE DRAWINGS

The same reference number represents the same element on all drawings. It should be understood that the drawings are not necessarily to scale.

FIG. 1 shows a system 10 having two-source flow control for batch processing.

FIG. 2 shows a data processing schematic 200 of the flow meter system 100 configured for two-source flow control for batch processing described with reference to FIG. 1.

FIG. 3 shows a system 30 for two-source flow control for batch processing.

FIG. 4 shows a data processing schematic 400 of the flow meter system 300 for two-source flow control for batch processing described with reference to FIG. 3.

FIG. 5 shows a system 50 for two-source flow control for batch processing.

FIG. 6 shows a data processing schematic 600 of the flow meter system 500 for two-source flow control for batch processing described with reference to FIG. 5.

FIG. 7 shows a system 70 for two-source flow control for batch processing.

FIG. 8 shows a data processing schematic 800 of the flow meter system 700 for two-source flow control for batch processing described with reference to FIG. 7.

FIG. 9 shows a method 900 for two-source flow control for batch processing.

FIG. 10 shows a vibratory meter 1005 configured for two-source flow control for batch processing.

FIG. 11 shows a meter electronics 1020 configured for two-source flow control for batch processing.

DETAILED DESCRIPTION

FIGS. 1 – 11 and the following description depict specific examples to teach those skilled in the art how to make and use the best mode of embodiments of two-source flow control for batch processing. For the purpose of teaching inventive principles, some conventional aspects have been simplified or omitted. Those skilled in the art will appreciate variations from these examples that fall within the scope of the present description. Those skilled in the art will appreciate that the features described below can be combined in various ways to form multiple variations of the two-source flow control for batch processing. As a result, the embodiments described below are not limited to the specific examples described below, but only by the claims and their equivalents.

**FIG. 1** shows a system 10 having two-source flow control for batch processing. As shown in FIG. 1, the system 10 is comprised of a concentrate source 10C and a dilutant source 10D, which comprise the two inlets of the two-source flow control for batch processing. The concentrate source 10C and dilutant source 10D are shown as being comprised of a concentrate supply 12C and dilutant supply 12D that are fluidly coupled to a flow meter system 100. The flow meter system 100 is fluidly coupled to a mixing tank 10T. The flow meter system 100 is comprised of a concentrate flow meter 110C and a dilutant flow meter 110D that are respectively fluidly coupled to the concentrate supply 12C and the dilutant supply 12D so as to receive a concentrate and a dilutant. The concentrate flow meter 110C and the dilutant flow meter 110D are also shown as being fluidly coupled to a concentrate valve 120C and a dilutant valve 120D. The concentrate valve 120C and the dilutant valve 120D are fluidly coupled to the mixing tank 10T.

The concentrate flow meter 110C and the dilutant flow meter 110D are shown as respectively being comprised of a concentrate sensor assembly 112C and dilutant sensor assembly 112D and a concentrate meter electronics 114C and dilutant meter electronics 114D. The concentrate meter electronics 114C and the dilutant meter electronics 114D are respectively mechanically and electrically coupled to the concentrate sensor assembly 112C and dilutant sensor assembly 112D. The concentrate meter electronics 114C and the dilutant meter electronics 114D are respectively communicatively coupled to the concentrate supply 12C and the dilutant supply 12D. The concentrate meter electronics 114C and dilutant meter electronics 114D are also communicatively coupled, such as, for example, electrically coupled, to a system computer 130. The system computer 130 is also communicatively coupled to a mixture concentration meter 140.

The concentrate meter electronics 114C, dilutant meter electronics 114D, concentrate valve 120C, dilutant valve 120D, system computer 130, concentrate supply 12C, dilutant supply 12D, and mixture concentration meter 140 may be communicatively coupled to each other over any suitable ports, cables, protocol, etc. For example, as shown in FIG. 1, the concentrate meter electronics 114C, dilutant meter electronics 114D, concentrate valve 120C, dilutant valve 120D, system computer 130, and mixture concentration meter 140 are shown as being communicatively coupled to each other over unshared communication lines illustrated by dashed lines. However, the dashed lines may represent channels, command/response protocols, etc., over a single bus line, such as a Modbus line, that is coupled to each of the concentrate meter electronics 114C, dilutant meter electronics 114D, concentrate valve 120C, dilutant valve 120D, system computer 130, and mixture concentration meter 140. In such a configuration, the system computer 130 may serve as a master to the concentrate meter electronics 114C, dilutant meter electronics 114D, concentrate valve 120C, dilutant valve 120D, and mixture concentration meter 140. Regardless of how the concentrate meter electronics 114C, dilutant meter electronics 114D, concentrate valve 120C, dilutant valve 120D, system computer 130, and mixture concentration meter 140 communicate with each other, a concentration of the mixture may be determined and controlled.

As to the fluid couplings, the concentrate supply 12C and dilutant supply 12D may respectively provide a concentrate and a dilutant to the concentrate flow meter 110C and dilutant flow meter 110D. For example, the concentrate supply 12C and dilutant supply 12D may be comprised of a tank, conduit, pumps, valves, and/or the like controlled by the concentrate meter electronics 114C and dilutant meter electronics 114D to provide and/or control a flow of the concentrate and/or dilutant to the concentrate flow meter 110C and dilutant flow meter 110D. The concentrate may be any suitable concentrate that can be diluted, such as, for example an alcohol/water mixture of very high proof, an acid or base respectively having a very acidic or basic pH values, a cleaning compound that can be used by professional services or consumers, depending on concentration, etc. The dilutant may be any suitable dilutant for the concentrate such as, for example, water, alcohol, diesel, etc.

The concentrate flow meter 110C and dilutant flow meter 110D are respectively configured to receive and measure the concentrate and dilutant. For example, the concentrate flow meter 110C and dilutant flow meter 110D may be configured to measure a flow rate, density, viscosity, and/or the like of the concentrate and dilutant. The measured values may be referred to as fluid parameter values. The concentrate flow meter 110C and/or the dilutant flow meter 110D may also be configured to determine other values, such as inferred values, based on the measured values, such as a concentration of the concentrate. Additionally, or alternatively, the concentrate flow meter 110C and/or dilutant flow meter 110D may also be configured to determine an amount of the dilutant and the concentrate that will result in a mixture of a desired concentration, as will be described in more detail in the following.

The concentrate sensor assembly 112C and dilutant sensor assembly 112D are respectively configured to sense one or more observable characteristics of the concentrate and dilutant. For example, the concentrate sensor assembly 112C and dilutant sensor assembly 112D may be respectively configured to sense a vibration frequency of a measuring conduit, tine, or the like. Additionally, or alternatively, the concentrate sensor assembly 112C and dilutant sensor assembly 112D may sense a time delay, such as Coriolis force induced time delay, between two conduits in each of the concentrate sensor assembly 112C and dilutant sensor assembly 112D. Other flow meters may be employed, such as those that sense on, for example, a transit time between paired ultrasonic transducers. The concentrate sensor assembly 112C and dilutant sensor assembly 112D may provide signals carrying information, such as voltage proportionality, on the sensed characteristic to the concentrate meter electronics 114C and dilutant meter electronics 114D.

The concentrate meter electronics 114C and dilutant meter electronics 114D are configured to receive and/or provide signals to and/or from the concentrate sensor assembly 112C and dilutant sensor assembly 112D. The concentrate meter electronics 114C and dilutant meter electronics 114D may process the signals received from the concentrate sensor assembly 112C and dilutant sensor assembly 112D to determine one or more measured values of a fluid being sensed by the concentrate sensor assembly 112C and dilutant sensor assembly 112D. Accordingly, the concentrate meter electronics 114C and dilutant meter electronics 114D may include signal conditioning circuits, digital to analog converters, one or more processors, memories, amplifiers, input and/or output ports, etc. Other values, which may be referred to as inferred values, such as a concentration value of the concentrate, can also be determined. For example, the concentrate meter electronics 114C may include a concentration determination routine that determines a concentration from a measured density value.

The concentrate meter electronics 114C and/or dilutant meter electronics 114D may also include batching operations that, for example, control a quantity, such as a total mass and/or volume, of the concentrate and the dilutant is provided to the mixing tank 10T. For example, concentrate meter electronics 114C and dilutant meter electronics 114D may provide a signal to the concentrate valve 120C and/or dilutant valve 120D to begin flowing the concentrate and/or dilutant. While the concentrate and/or the dilutant are flowing, the concentrate meter electronics 114C and dilutant meter electronics 114D may measure a mass flow rate, continuously totalize the measured mass flow rate, and determine when the totalized measured mass flow rate equals a predetermined value. It should be appreciated that other methods, additionally or alternatively, may be employed, such as timing or counting a measured constant flow rate, etc.

The concentrate meter electronics 114C and dilutant meter electronics 114D may also provide a signal to the concentrate valve 120C and/or dilutant valve 120D to discontinue flowing the concentrate and dilutant. It should be appreciated that the signal sent to the concentrate valve 120C and/or dilutant valve 120D may occur at some time before the predetermined amount of the concentrate and/or dilutant is provided. For example, as shown in FIG. 1, a volume of fluid is respectively between the concentrate valve 120C and dilutant valve 120D and the mixing tank 10T. A timing of the signals provided to the concentrate valve 120C and dilutant valve 120D may accommodate the quantity of fluid between the concentrate valve 120C and dilutant valve 120D and the mixing tank 10T.

Accordingly, the concentrate flow meter 110C and dilutant flow meter 110D can provide a predetermined amount of the concentrate and the dilutant to the mixing tank 10T. The concentrate flow meter 110C and dilutant flow meter 110D may also provide the predetermined amount of concentrate and dilutant simultaneously. It should be appreciated that the concentrate flow meter 110C and dilutant flow meter 110D can initiate the batching operation as soon as the predetermined amount of the concentrate and dilutant are known. Additionally, the flow rate of the concentrate and the dilutant can be controlled with, for example, pumps or the like to obtain a desired throughput, equal flow times of the concentrate and dilutant, etc. Additionally, or alternatively, the concentrate meter electronics 114C and dilutant meter electronics 114D can also provide a signal to, for example, the system computer 130, that the predetermined amount of the concentrate and dilutant has been provided.

The system computer 130 may be a computer configured to, for example, provide and set batch targets and/or execute batch control operations on the dilutant flow meter 110D and/or concentrate flow meter 110C. These routines may be referred to as a mixture concentration routine. The mixture concentration routine may receive as user input values a desired mixture concentration. The mixture concentration routine may also receive as a user input value a concentration value of the concentrate provided by the concentrate supply 12C. Accordingly, the system computer 130 may include a local operator interface (LOI) that a user can employ to input the desired mixture concentration and/or the concentration of the concentrate provided by the concentrate supply 12C.

The mixture concentration meter 140 may be configured to measure and/or determine a concentration of the mixed fluid or mixture in the mixing tank 10T. For example, the mixture concentration meter 140 may be a densitometer that includes a concentration routine that determines a concentration from the measured density. Accordingly, the mixture concentration meter 140 may include signal conditioning, analog-to-digital converters, processor, and memories that can convert sensed mixture characteristics to a density value and determine a concentration from the density value.

By way of illustration, if the mixture in the mixing tank 10T is an alcohol/water mixture, then the memory of the mixture concentration meter 140 may include a density-to-concentration relationship, such as a table that relates density values to alcohol-water concentration values.

As discussed above, the concentrate flow meter 110C and/or dilutant flow meter 110D can be configured to perform batching operations and determine a concentration of the concentrate. The concentrate flow meter 110C and dilutant flow meter 110D could also be configured to determine an amount of the concentrate and the dilutant to achieve a desired concentration of the concentrate in the mixed fluid in the mixing tank 10T. For example, the concentrate meter electronics 114C and the dilutant meter electronics 114D may receive a ratio from the system computer 130 and determine from the ratio an amount of the concentrate and the dilutant to obtain the desired concentration. Accordingly, the concentrate meter electronics 114C, dilutant meter electronics 114D, and/or system computer 130 may be configured to perform any suitable portions of a batching operation and/or a mixture concentration routine.

It should be appreciated from FIG. 1, that the concentrate source 10C is comprised of the concentrate supply 12C, the concentrate flow meter 110C and the concentrate valve 120C. Similarly, the dilutant source 10D is comprised of the dilutant supply 12D, the dilutant flow meter 110D, and the dilutant valve 120D. Accordingly, the concentrate source 10C may provide the predetermined quantity of the concentrate to the mixing tank 10T and the dilutant source 10D may provide the predetermined quantity of the dilutant to the mixing tank 10T. However, the batching operation may not result in the desired concentration of the concentrate in the mixed fluid or mixture in the mixing tank 10T. Accordingly, the mixture concentration meter 140 may be used to determine a concentration of the mixture and provide the concentration of the mixture to the system computer 130 so that a second batch operation can be performed that corrects the concentration of the mixture.

Accordingly, with two inlets, such as the concentrate source 10C and the dilutant source 10D described above, equipped with batching flow meters, such as, for example, Coriolis flow meters, ultrasonic flow meters, etc., where one of the flow meters is for the dilutant and the other flow meter for the concentrate, it is possible to automate the mixing/dilution process by dosing in both components simultaneously. The two flow meters, such as the concentrate flow meter 110C and dilutant flow meter 110D, on the inlets could work as a system and could carry out the mixing automatically with minimal user input. Small adjustments can also be made automatically and at the end of a batching by using the mixture concentration meter 140 installed in the mixing tank 10T.

User inputs could be a starting concentration of the concentrate and a target volume or mass and concentration of the mixture. In an exemplary configuration, since Coriolis technology measures both mass flow and volume flow (and respective totals), this technology can work with concentrations by mass as well as by volume. Hence, users may need to select which concentration type they would like to work with. From there, a processor, such as a processor in the concentrate meter electronics 114C, dilutant meter electronics 114D, and/or system computer 130 described above, can calculate the amounts of each component to add:

$$T_c = T_m \times \frac{C_t}{C_c}\text{; and} \qquad [1]$$

$$T_d = T_m - T_c; \qquad [2]$$

where:

$T_c$= total amount of concentrate (e.g., volume or mass, which may be a calculated value);

$T_d$= total amount of dilutant (e.g., volume or mass, which may be a calculated value);

$T_m$= target amount of mixture (e.g., volume or mass, which may be a user input);

$C_t$= target final concentration (e.g., %, which may be a user input); and

$C_c$= concentration of raw concentrate (e.g., %, which may be a user input or calculated value).

It should be appreciated that, for the concentration of the raw concentrate $C_c$, only in the case of concentration by mass, a starting concentration of the concentrate may not be required as a user input. More specifically, for example, a Coriolis meter on the concentrate inlet, such as the concentrate source 10C described above, could measure a concentration by using a concentration determination routine (e.g., a concentration determination software) after a brief, initial period of stable flow. That measurement could then be automatically integrated into the calculations above for subsequent mixture calculation routine.

After any necessary user inputs are made, the user may submit them through a user interface and total amount of concentrate added $T_c$ and total amount of dilutant added $T_d$ are calculated – i.e., predetermined or "to be added." The batching operation will then be "ready to start" and the user can begin or execute the batching operation through the same interface. Once the batching operation is actuated, the system, such as the system 10, can immediately and simultaneously batch the total amount of concentrate added $T_c$ and total amount of dilutant added $T_d$ into the mixing tank, such as the mixing tank 10T described above. It may be preferable that the concentrate and dilutant inlets are two separate streams into the mixing tank, as is shown in FIG. 1 where the concentrate source 10C and the dilutant source 10D are separate inlets into the mixing tank 10T.

In addition to the inlet flow rate measurements, such as Coriolis flow rate measurements, a concentration measurement can also be taken of the final, mixed solution or mixture, using, for example, the mixture concentration meter 140 described above. By way of illustration, the concentration measurement can be made with a fork density meter ("FDM") installed directly into the mixing tank, a Coriolis flow meter installed in a circulation loop off the mixing tank, etc. Incorporating one of these measurements would effectively provide a check/validation meter for the dilution process of a preceding batching operation and allow for small corrections to be made. With batching systems with flow meters on both inlets to the mixing tank, these adjustments could be executed easily and automatically after a first batching operation concludes. If the resulting concentration of the mixture is too high, more dilutant could be added. The amount of dilutant to be added for correction would be automatically calculated after the FDM or recirculating Coriolis meter provides the final concentration check as an input:

$$T_d = T_m\left(\frac{C_m}{C_t} - 1\right); \qquad [3]$$

where:

$T_d$ = amount of dilutant to be added for correction;

$C_m$ = concentration of uncorrected mixture (measured by check meter);

$C_t$ = correct (original target) concentration; and

$T_m$= amount of uncorrected mixture.

Similarly, if the concentration after the first batching operation is too low, more concentrate could be added. The amount of concentrate to be added for correction would be automatically calculated after the FDM or recirculating Coriolis meter provides the concentration of the mixture as an input:

$$T_c = \frac{(C_t T_m - C_c T_{ci})}{C_c - C_t}; \qquad [4]$$

$T_c$ = amount of concentrate to be added for correction;

$T_{ci}$= initial amount of raw concentrate used for an uncorrected mixture (e.g., mixture obtained after a first batching operation);

$C_t$= correct (original target) concentration;

$T_m$= amount of uncorrected concentrate-dilutant mixture; and

$C_c$= concentration of raw concentrate.

It should be appreciated that the system can have various alternative or more particular architectures of the topology shown in FIG. 1. The following describes two exemplary architectures.

First exemplary architecture

A first architecture may be viewed as having a topology similar to the system 10 described with reference to FIG. 1. Accordingly, for the sake of simplicity, discussion of the first architecture will refer to the system 10 of FIG. 1 and describe more specific features of the first architecture. The first architecture involves the use of an industrial personal computer ("IPC") for data acquisition, calculations, and user interface as the system computer 130. The IPC can be configured to act as a Modbus master device for the inlet flow meter systems. The concentrate source 10C and the dilutant source 10D, which may be referred to as inlet control systems, may need to be equipped with meter electronics or transmitters, such as the concentrate meter electronics 114C and dilutant meter electronics 114D described above, which support standard batching software, Modbus remote terminal unit ("Modbus-RTU") or transmission control protocol ("TCP") communication, and concentration measurement routines or software. The concentration measurement routines or software may be on the concentrate flow meter, such as the concentrate flow meter 110C described with reference to FIG. 1, in the case of automatic determination of a concentration of the raw concentrate. It should be appreciated in this architecture that the mixture concentration check meter may need to be equipped with concentration measurement routines or software.

In this first architecture, the system computer 130 will interact with the concentrate source 10C and the dilutant source 10D by relaying data over an interface, automatically configuring batch targets on the concentrate source 10C and the dilutant source 10D and actuating the batches on each of the concentrate source 10C and the dilutant source 10D. The meter electronics or transmitters equipped with batching software will execute the batches and all control (e.g., relays, valve/pump timing, automatic overshoot compensation ("AOC"), etc.) independently after being actuated by the IPC. It may be preferable that the LOI used for this first architecture is a web-interface software. The web interface software program may run on the system computer 130 and is interacted with through a connected, capacitive touch display. The particular arrangement of the algorithms or software and the variables for the first architecture are described in the following.

**FIG. 2** shows a data processing schematic 200 of the flow meter system 100 configured for two-source flow control for batch processing described with reference to FIG. 1. As shown in FIG. 2, the data processing schematic 200 is comprised of the system computer 130, which in the first architecture is referred to as the IPC, communicatively coupled to the concentrate meter electronics 114C and the dilutant meter electronics 114D. The concentrate meter electronics 114C and the dilutant meter electronics 114D are shown as being comprised of algorithms, calculated values, and control output portions. In the algorithm portion, an operational algorithm and a batch operation software are shown for both the concentrate meter electronics 114C and the dilutant meter electronics 114D. In the calculated values portion, a density value, a mass flow rate ("MFR") and an accumulated MFR value are shown. However, the concentrate meter electronics 114C also includes a concentrate concentration determination software and a concentrate concentration value whereas the dilutant meter electronics 114D does not.

The system computer 130 is shown as being comprised of a user input value(s) portion, an algorithm(s) portion, and a calculated value(s) portion. The user input value(s) includes a target amount of mixture and a target concentration, which are target values for the mixture in the mixing tank 10T. The algorithm(s) portion is shown as including a batch target(s) software and a final concentration algorithm. The calculated value(s) portion is comprised of a target amount of concentration and a target amount of dilutant.

The operational algorithm in the concentrate meter electronics 114C and the dilutant meter electronics 114D respectively calculates the density and mass flow rate values based on sensor signals from the concentrate sensor assembly 112C and the dilutant sensor assembly 112D. The concentrate concentration determination software can determine the concentrate concentration value of the concentrate in the concentrate sensor assembly 112C. It should be understood that the dilutant may be assumed to be 100 percent pure and therefore the dilutant meter electronics 114D does not include a concentration determination software or the concentration values, although alternative dilutant meter electronics may include dilutant concentration determination software in, for example, not especially pure applications.

The batch operation algorithms in the concentrate meter electronics 114C and/or the dilutant meter electronics 114D may respectively control a MFR of the concentrate and the dilutant based on the target amount of concentrate and the target amount of dilutant. For example, the batch operation algorithm may control the operations of the concentrate supply 12C, dilutant supply 12D, concentrate valve 120C, and/or the dilutant valve 120D to meet the target amount of concentrate and the target amount of dilutant.

The batch target software in the system computer 130 may calculate batch target values based on the target amount of mix and the target concentration value. For example, the batch target(s) software may receive the concentration value of the concentrate from the concentrate meter electronics 114C and calculate an amount of the dilutant and the concentration that would result in the mixture in the mixing tank 10T having the target amount of the mix and the target concentration.

The final concentration algorithm may calculate the actual concentration value of the mixture based on signals from the mixture concentration meter 140. The final concentration algorithm may be run after the mixing tank 10T is filled. However, it should be understood that the final concentration algorithm may be based on a general concentration algorithm that can be performed at any time in non-batching operations. Accordingly, the final concentration algorithm may be performed after a batch operation is run to determine the final concentration value.

The system computer 130 may compare the final concentration value with the target concentration value. If the final concentration value differs from the target concentration value, for example by more than a threshold amount, then another batching operation may be performed. Accordingly, the batch target(s) software may again calculate target batch values based on the target amount of mix and the target concentration as before but can also consider a difference between the final concentration and the target concentration. This correction batch operation may simply involve flowing a certain amount of dilute if the final concentration is too high and a certain amount of concentrate if the final concentration is too low.

As can be appreciated, the system computer 130 does not control the flow of the concentrate or the dilutant. Instead, the system computer 130 outputs the target amount of concentrate and the target amount of dilutant respectively to the concentrate meter electronics 114C and the dilutant meter electronics 114D. Alternative architectures may be employed, an example of which is described in the following.

Second exemplary architecture

**FIG. 3** shows a system 30 for two-source flow control for batch processing. As shown in FIG. 3, the system 30 is comprised of a concentrate source 30C and a dilutant source 30D. The concentrate source 30C and dilutant source 30D are shown as being comprised of a concentrate supply 32C and dilutant supply 32D that are fluidly coupled to a flow meter system 300. The flow meter system 300 is fluidly coupled to the mixing tank 10T described above with reference to FIG. 1. The flow meter system 300 is comprised of a concentrate flow meter 310C and a dilutant flow meter 310D that are respectively fluidly coupled to the concentrate supply 32C and the dilutant supply 32D so as to receive a concentrate and a dilutant. The concentrate flow meter 310C and the dilutant flow meter 310D are also shown as being fluidly coupled to the concentrate valve 120C and the dilutant valve 120D described above with reference to FIG. 1. The concentrate valve 120C and the dilutant valve 120D are fluidly coupled to the mixing tank 10T.

The concentrate flow meter 310C and the dilutant flow meter 310D are shown as respectively being comprised of a concentrate sensor assembly 112C and dilutant sensor assembly 112D and a shared meter electronics 314, in contrast to the concentrate meter electronics 114C and the dilutant meter electronics 114D. The meter electronics 314 is electrically coupled to the concentrate sensor assembly 112C and dilutant sensor assembly 112D. The meter electronics 314 may or may not be mechanically coupled to the concentrate sensor assembly 112C and/or dilutant sensor assembly 112D.

In contrast to the concentrate meter electronics 114C and the dilutant meter electronics 114D described above, the meter electronics 314 is not communicatively coupled to the concentrate supply 32C and the dilutant supply 32D. Instead, the system computer 330 is communicatively coupled to the concentrate supply 32C and the dilutant supply 32 so as to control a supply of the concentrate and the dilutant. The meter electronics 314 is also communicatively coupled, such as, for example, electrically coupled, to a system computer 330. The system computer 330 is also communicatively coupled to the mixture concentration meter 140 described above with reference to FIG. 1.

The meter electronics 314, concentrate valve 120C, dilutant valve 120D, system computer 330, concentrate supply 32C, dilutant supply 32D, and mixture concentration meter 140 may be communicatively coupled to each other over any suitable ports, cables, protocol, etc. For example, as shown in FIG. 3, the meter electronics 314, concentrate valve 120C, dilutant valve 120D, system computer 330, and mixture concentration meter 140 are shown as being communicatively coupled to each other over unshared communication lines illustrated by dashed lines. However, the dashed lines may represent a single bus line, such as a Modbus line, that is coupled to each of the meter electronics 314, concentrate valve 120C, dilutant valve 120D, system computer 330, and mixture concentration meter 140. In such a configuration, the system computer 330 may serve as a master to the meter electronics 314, concentrate valve 120C, dilutant valve 120D, and mixture concentration meter 140. Regardless of how the meter electronics 314, concentrate valve 120C, dilutant valve 120D, system computer 330, and mixture concentration meter 140 communicate with each other, a concentration of the mixture may be determined and controlled.

As to the fluid couplings, the concentrate supply 32C and dilutant supply 32D may respectively provide a concentrate and a dilutant to the concentrate flow meter 310C and dilutant flow meter 310D. For example, the concentrate supply 32C and dilutant supply 32D may be comprised of a tank, conduit, pumps, valves, and/or the like controlled by the system computer 330 to provide and/or control a flow of the concentrate and/or dilutant to the concentrate flow meter 310C and dilutant flow meter 310D. The concentrate may be any suitable concentrate that can be diluted, such as, for example an alcohol/water mixture of very high proof, an acid or base having a very acidic or basic pH values, a cleaning compound that can be used by professional services or consumers, depending on concentration, etc. The dilutant may be any suitable dilutant for the concentrate, such as, for example, water, alcohol, diesel, etc.

The concentrate flow meter 310C and dilutant flow meter 310D are respectively configured to receive and measure the concentrate and dilutant. For example, the concentrate flow meter 310C and dilutant flow meter 310D may be configured to measure a flow rate, density, viscosity, and/or the like of the concentrate and dilutant. The measured values may be referred to as fluid parameter values. The concentrate flow meter 310C and/or the dilutant flow meter 310D may also be configured to determine other values based on the measured values, such as a concentration of the concentrate. However, in contrast to the concentrate flow meter 110C and the dilutant flow meter 110D described with reference to FIG. 1, the concentrate flow meter 310C and/or dilutant flow meter 310D may not be configured to determine an amount of the dilutant and the concentrate that will result in a mixture of a desired concentration.

As described with reference to FIG. 1, the concentrate sensor assembly 112C and dilutant sensor assembly 112D are respectively configured to sense one or more observable characteristics of the concentrate and dilutant. For example, the concentrate sensor assembly 112C and dilutant sensor assembly 112D may be respectively configured to sense a vibration frequency of a measuring conduit, tine, or the like. Additionally, or alternatively, the concentrate sensor assembly 112C and dilutant sensor assembly 112D may sense a time delay, such as Coriolis force induced time delay, between two conduits in each of the concentrate sensor assembly 112C and dilutant sensor assembly 112D. Other flow meters may be employed, such as those that sense, for example, a transit time between paired ultrasonic transducers. The concentrate sensor assembly 112C and dilutant sensor assembly 112D may provide signals carrying information, such as voltage proportionality, reflecting the sensed characteristic to the meter electronics 314.

The meter electronics 314 is configured to receive and/or provide signals to and/or from the concentrate sensor assembly 112C and dilutant sensor assembly 112D.

The meter electronics 314 may process the signals received from the concentrate sensor assembly 112C and dilutant sensor assembly 112D to determine one or more fluid parameter values of a fluid being sensed by the concentrate sensor assembly 112C and dilutant sensor assembly 112D. Accordingly, the concentrate meter electronics 114C and dilutant meter electronics 114D may include signal conditioning circuits, digital to analog converters, one or more processors, memories, amplifiers, input and/or output ports, etc. In contrast to the concentrate meter electronics 114C and the dilutant meter electronics 114D described with reference to FIG. 1, however, the meter electronics 314 may not calculate other values, such as a concentration of the concentrate.

For example, the meter electronics 314 may not include a concentration determination routine that determines a concentration from a measured density value. The meter electronics 314 may also not include batching operations that, for example, control a quantity, such as a total mass and/or volume, of the concentrate and the dilutant is provided to the mixing tank 10T. Accordingly, the meter electronics 314 may not provide a signal to the concentrate valve 120C and the dilutant valve 120D to control a flow of the concentrate and dilutant. Instead, the system computer 330 may determine values based on the density and/or the MFR provided by the meter electronics 314, such as a concentration of the concentrate, can be determined. For example, the system computer 330 may include a concentration determination routine that determines a concentration from a measured density value.

The system computer 330 may also provide a signal to the concentrate valve 120C and/or dilutant valve 120D to discontinue flowing the concentrate and dilutant. Additionally, or alternatively, the system computer 330 can also provide a signal that the predetermined amount of the concentrate and dilutant has been provided. It should be appreciated that the signal sent to the concentrate valve 120C and/or dilutant valve 120D may occur at some time before the predetermined amount of the concentrate and/or dilutant is provided using an automatic overflow compensation routine. For example, as shown in FIG. 1, a volume of fluid is respectively between the concentrate valve 120C and dilutant valve 120D and the mixing tank 10T. A timing of the signals provided to the concentrate valve 120C and dilutant valve 120D may accommodate the quantity of fluid between the concentrate valve 120C and dilutant valve 120D and the mixing tank 10T.

Accordingly, the concentrate flow meter 310C and dilutant flow meter 310D can provide a predetermined amount of the concentrate and the dilutant to the mixing tank 10T. The concentrate flow meter 310C and dilutant flow meter 310D may also provide the predetermined amount of concentrate and dilutant substantially simultaneously, although any suitable relative timing, flow rates, start and/or stop times, etc., may be employed. It should be appreciated that the concentrate flow meter 310C and dilutant flow meter 310D can initiate the batching operation as soon as the predetermined amount of the concentrate and dilutant are known by the system computer 330. Additionally, the flow rate of the concentrate and the dilutant can be controlled with, for example, pumps or the like to obtain a desired throughput, equal flow times of the concentrate and dilutant, etc.

Accordingly, in this second architecture, rather than the concentrate flow meter 310C and dilutant flow meter 310D each having their own batching transmitter, the meter electronics 314 can be used for dual metering of each inlet: concentrate and dilutant. That is, the meter electronics 314 receives and processes signals from the concentrate sensor assembly 112C and dilutant sensor assembly 112D to determine fluid parameters, such as mass flow rate, density, viscosity, etc. Accordingly, the meter electronics may be a combination of some or all of the functions of the concentrate meter electronics 114C and dilutant meter electronics 114D described above in a single form factor. In contrast to the concentrate meter electronics 114C and dilutant meter electronics 114D described above, the meter electronics 314 may not be mechanically coupled to the concentrate sensor assembly 112C and dilutant sensor assembly 112D.

In system 30 shown in FIG. 3, the meter electronics 314 may be communicatively coupled to a single system computer 330 equipped with batching software and concentration measurement software for raw concentrate determination. Accordingly, the system computer 330 may be similar to the system computer 130 described with reference to FIG. 1. With more particularity, the system computer 330 could be responsible for providing the LOI, performing all calculations, and executing batch control for both inlets simultaneously. Because the system computer 330 controls both the concentrate source 30C and dilutant source 30D, the system computer 330 may need twice as many discrete outputs for pump or valve actuation. In the simple case of single stage batching, the system computer 330 may need at least two discrete outputs.

The system computer 330 may also need to provide an external input for the mixture concentration meter 140 concentration measurement, similar to the system computer 130 shown in FIG. 1. This can be done via a channel on the system computer 330, for example, by using 4-20 mA signal or digital highway addressable remote transducer ("HART") protocol.

Therefore, as can be appreciated, the system 30 distributes the batch target(s), batch operation, concentration, and final concentration algorithms/software and the concentration and target values differently than the system 10, as the following explains in more detail.

**FIG. 4** shows a data processing schematic 400 of the flow meter system 300 for two-source flow control for batch processing described with reference to FIG. 3. As shown in FIG. 4, the data processing schematic 400 comprises the system computer 330 communicatively coupled to the meter electronics 314. The system computer 330 may be referred to as a transmitter and the meter electronics 314 may be referred to as a core processor to distinguish their functions when compared to the IPC and the concentrate and dilutant meter electronics 114C, 114D described with reference to FIG. 1, although any suitable terminology may be utilized. The distinctions become apparent in the following discussion.

As described above with reference to FIG. 3, the meter electronics 314 is electrically coupled to the concentrate sensor assembly 112C and the dilutant sensor assembly 112D. The meter electronics 314 is shown as being comprised of algorithms, calculated values, and control output portions. In the algorithm portion, an operational algorithm is shown. In the calculated values portion, a density value, a mass flow rate ("MFR") and an accumulated MFR value are shown. The operational algorithm in the meter electronics 314 calculates the density and mass flow rate values based on sensor signals from the concentrate sensor assembly 112C and the dilutant sensor assembly 112D. The meter electronics 314 may therefore be viewed as performing core processing to determine, for example, measured fluid parameter values from which other values may be determined. The measured fluid parameter values are provided to the system computer 330.

The system computer 330 is shown as being comprised of a user input value(s) portion, an algorithm(s) portion, and a calculated value(s) portion. The user input value(s) includes a target amount of mixture and a target concentration, which are target values for the mixture. The algorithm(s) portion is shown as including a concentrate concentration determination software, batch target(s) software, batch operation, and a final concentration algorithm. The calculated value(s) portion is comprised of a concentrate concentration, a final concentration, a target amount of concentration and a target amount of dilutant.

The concentrate concentration determination software can determine a concentrate concentration value of the concentrate in the concentrate sensor assembly 112C. It should be understood that the dilutant may be assumed to be 100 percent pure and therefore the system computer 330 does not include a concentration determination software or concentration values for the dilutant.

The batch operation algorithms in the system computer 330 may respectively control a MFR of the concentrate and the dilutant based on the target amount of concentrate and the target amount of dilutant. For example, the batch operation algorithm may control the operations of the concentrate supply 32C, dilutant supply 32D, concentrate valve 120C, and/or the dilutant valve 120D to meet the target amount of concentrate and the target amount of dilutant.

The batch target(s) software in the system computer 330 may calculate batch target values based on the target amount of mix and the target concentration value. For example, the batch target(s) software may receive the concentration value of the concentrate from the concentrate flow meter 310C and calculate an amount of the dilutant and the concentrate that would result in the mixture in the mixing tank 10T having the target amount of the mix and the target concentration.

The final concentration algorithm may calculate the actual concentration value of the mixture based on signals from the mixture concentration meter 140. The final concentration algorithm may be run after the mixing tank 10T is filled. However, it should be understood that the final concentration algorithm may be based on a general concentration algorithm that can be performed at any time in non-batching operations. Accordingly, the final concentration algorithm may be performed after a batch operation is run to determine the final concentration value.

The system computer 330 may compare the final concentration value with the target concentration value. If the final concentration value differs from the target concentration value, for example by more than a threshold amount, then another batching operation may be performed. Accordingly, the batch target(s) software may again calculate target batch values based on the target amount of mix and the target concentration as before but can also consider a difference between the final concentration and the target concentration. This correction batch operation may simply involve flowing a certain amount of dilute if the final concentration is too high and a certain amount of concentrate if the final concentration is too low.

As can be appreciated, the foregoing first and second architectures utilized two flow meters that independently measured the concentrate and the dilutant flowing to the mixture tank 10T. The following discusses architectures that employ a single flow meter.

Third exemplary architecture

**FIG. 5** shows a system 50 for two-source flow control for batch processing. As shown in FIG. 5, the system 50 is comprised of a concentrate source 50C and a dilutant source 50D. The concentrate source 50C and dilutant source 50D are shown as being comprised of a concentrate supply 52C and dilutant supply 52D that are fluidly coupled to a flow meter system 500. The flow meter system 500 is fluidly coupled to the mixing tank 10T described above with reference to FIG. 1. The flow meter system 500 is comprised of a concentrate-dilutant flow meter 510CD that is fluidly coupled to the concentrate supply 52C and the dilutant supply 52D via a mixer 520 so as to receive a concentrate and a dilutant.

The concentrate-dilutant flow meter 510CD is also shown as being fluidly coupled to the mixing tank 10T. A valve is not between the concentrate-dilutant flow meter 510CD and the mixing tank 10T, in contrast to the concentrate valve 120C and the dilutant valve 120D described above. Instead, the mixer 520 is between the concentrate-dilutant flow meter 510CD and the concentrate and dilutant supplies 52C, 52D. It should be appreciated that the mixer 520 is not necessarily used to mix two fluids together in the mixer 520, but can receive and convey one of the concentrate and the dilutant respectively provided by the concentrate supply 52C and the dilutant supply 52D. That is, the concentrate and the dilutant may be provided to the concentrate-dilutant flow meter 510CD asynchronously.

The concentrate-dilutant flow meter 510CD is shown as being comprised of a sensor assembly 512CD and a meter electronics 514CD. The meter electronics 514CD is electrically coupled to the sensor assembly 512CD. The meter electronics 514CD may or may not be mechanically coupled to the sensor assembly 512CD. Similar to the meter electronics 314 described above with reference to FIG. 3, the meter electronics 514CD is not communicatively coupled to the concentrate supply 52C and the dilutant supply 52D. Instead, the system computer 530 is communicatively coupled to the concentrate supply 52C and the dilutant supply 52D so as to control a supply of the concentrate and the dilutant. The meter electronics 514CD is also communicatively coupled, such as, for example, electrically coupled, to a system computer 530. The system computer 530 is also communicatively coupled to the mixture concentration meter 140 described above with reference to FIG. 1.

The meter electronics 514CD, system computer 530, concentrate supply 52C, dilutant supply 52D, and mixture concentration meter 140 may be communicatively coupled to each other over any suitable ports, cables, protocol, etc. For example, as shown in FIG. 1, the meter electronics 514CD, system computer 530, and mixture concentration meter 140 are shown as being communicatively coupled to each other over unshared communication lines illustrated by dashed lines. However, the dashed lines may represent a single bus line, such as a Modbus line, that is coupled to each of the meter electronics 514CD, system computer 530, and mixture concentration meter 140. In such a configuration, the system computer 530 may serve as a master to the meter electronics 514CD, concentrate supply 52C, dilutant supply 52D, and mixture concentration meter 140. Regardless of how the meter electronics 514CD, system computer 530, concentrate supply 52C, dilutant supply 52D, and mixture concentration meter 140 communicate with each other, a concentration of the mixture in the mixing tank 10T may be determined and controlled.

As to the fluid couplings, the concentrate supply 52C and dilutant supply 52D may respectively provide a concentrate and a dilutant to the concentrate-dilutant flow meter 510CD. For example, the concentrate supply 52C and dilutant supply 52D may be comprised of a tank, conduit, pumps, valves, and/or the like controlled by the system computer 530 to provide and/or control a flow of the concentrate and/or dilutant to the concentrate-dilutant flow meter 510CD. The concentrate may be any suitable concentrate that can be diluted, such as, for example an alcohol/water mixture of very high proof, an acid or base having very acidic or basic pH values, a cleaning compound that can be used by professional services or consumers, depending on concentration, etc. The dilutant may be any suitable dilutant for the concentrate, such as, for example, water, alcohol, diesel, etc.

The concentrate-dilutant flow meter 510CD are respectively configured to receive and measure the concentrate and dilutant. For example, the concentrate-dilutant flow meter 510CD may be configured to measure a flow rate, density, viscosity, and/or the like of the concentrate and dilutant. The measured values may be referred to as fluid parameter values. The concentrate-dilutant flow meter 510CD may also be configured to determine other values based on the measured values, such as a concentration of the concentrate. However, in contrast to the concentrate flow meter 110C and the dilutant flow meter 110D described with reference to FIG. 1, the concentrate-dilutant flow meter 510CD may not be configured to determine an amount of the dilutant and the concentrate that will result in a mixture of a desired concentration.

As described with reference to FIG. 1, the sensor assembly 512CD is configured to sense one or more observable characteristics of the concentrate and dilutant. For example, the sensor assembly 512CD may be configured to sense a vibration frequency of a measuring conduit, tine, or the like. Additionally, or alternatively, the sensor assembly 512CD may sense a time delay, such as Coriolis force induced time delay, between two conduits in the sensor assembly 512CD. Other flow meters may be employed, such as those that sense, for example, a transit time between paired ultrasonic transducers. The sensor assembly 512CD may provide signals carrying information, such as voltage proportionality, reflecting the sensed characteristic to the meter electronics 514CD.

The meter electronics 514CD is configured to receive and/or provide signals to and/or from the sensor assembly 512CD. The meter electronics 514CD may process the signals received from the sensor assembly 512CD to determine one or more fluid parameter values of a fluid being sensed by the sensor assembly 512CD. Accordingly, the meter electronics 514CD may include signal conditioning circuits, digital to analog converters, one or more processors, memories, amplifiers, input and/or output ports, etc.

The meter electronics 514CD may calculate other values, such as a concentration of the concentrate.

For example, the meter electronics 514CD may include a concentration determination routine that determines a concentration from a measured density value. However, the meter electronics 514CD may also not include batching operations that, for example, control a quantity, such as a total mass and/or volume, of the concentrate and the dilutant is provided to the mixing tank 10T. Accordingly, the meter electronics 514CD may not provide a concentrate and dilutant supplies 52C, 52D to control a flow of the concentrate and dilutant. Instead, the system computer 530 may determine values based on the density and/or the MFR provided by the meter electronics 514CD, such as a concentration of the concentrate, can be determined. For example, the system computer 530 may include a concentration determination routine that determines a concentration from a measured density value.

The system computer 530 may also provide a signal to the concentrate and dilutant supplies 52C, 52D to discontinue flowing the concentrate and dilutant. Additionally, or alternatively, the system computer 530 can also provide a signal that the predetermined amount of the concentrate and dilutant has been provided. It should be appreciated that the signal sent to the concentrate and dilutant supplies 52C, 52D may occur at some time before the predetermined amount of the concentrate and/or dilutant is provided using an automatic overflow compensation routine. For example, as shown in FIG. 1, a volume of fluid is respectively between the concentrate and dilutant supplies 52C, 52D and the mixing tank 10T. A timing of the signals provided to the concentrate and dilutant supplies 52C, 52D may accommodate the quantity of fluid between the concentrate and dilutant supplies 52C, 52D and the mixing tank 10T.

Accordingly, the concentrate-dilutant flow meter 510CD can provide a predetermined amount of the concentrate and the dilutant to the mixing tank 10T. The concentrate-dilutant flow meter 510CD may also provide the predetermined amount of concentrate and dilutant substantially asynchronously, or at different times, although any suitable relative timing, flow rates, start and/stop times, etc., may be employed. It should be appreciated that the concentrate-dilutant flow meter 510CD can initiate the batching operation as soon as the predetermined amount of the concentrate and dilutant is known by the system computer 530. Additionally, the flow rate of the concentrate and the dilutant can be controlled with, for example, pumps or the like to obtain a desired throughput, equal flow times of the concentrate and dilutant, etc.

Accordingly, in this third architecture, rather than concentrate-dilutant flow meter 510CD each having their own batching transmitter, the meter electronics 514CD can be used for metering of each of the concentrate and dilutant supply 52C, 52D. That is, the meter electronics 514CD receives and processes signals from the sensor assembly 512CD to determine fluid parameters, such as mass flow rate, density, viscosity, etc. Accordingly, the meter electronics 514CD may be a combination of some or all of the functions of the concentrate meter electronics 114C and the dilutant meter electronics 114D described above in a single form factor. In contrast to the concentrate meter electronics 114C and dilutant meter electronics 114D described above, the meter electronics 314 may not be mechanically coupled to the concentrate sensor assembly 112C and dilutant sensor assembly 112D.

In system 50 shown in FIG. 5, the meter electronics 514CD may be communicatively coupled to a single system computer 530 equipped with batching software and concentration measurement software for raw concentrate determination. Accordingly, the system computer 530 may be similar to the system computer 130 described with reference to FIG. 1. With more particularity, the system computer 530 could be responsible for providing the LOI, performing all calculations, and executing batch control for both inlets simultaneously. Because the system computer 530 controls both the concentrate source 50C and dilutant source 50D, the system computer 530 may need twice as many discrete outputs for pump or valve actuation. In the simple case of single stage batching, the system computer 530 may need at least two discrete outputs. The system computer 530 may also need to provide an external input for the mixture concentration meter 140 concentration measurement, similar to the system computer 130 shown in FIG. 1. This can be done via a channel on the system computer 530, for example, by using 4-20 mA signal or digital highway addressable remote transducer ("HART") protocol.

Therefore, as can be appreciated, the system 50 distributes the batch target(s), batch operation, concentration, and final concentration algorithms/software and the concentration and target values differently than the system 30, as the following explains in more detail.

**FIG. 6** shows a data processing schematic 600 of the flow meter system 500 for two-source flow control for batch processing described with reference to FIG. 5. As shown in FIG. 6, the data processing schematic 600 comprises the system computer 530 communicatively coupled to the meter electronics 514CD. As described above with reference to FIG. 5, the meter electronics 514CD is electrically coupled to the sensor assembly 512CD. The meter electronics 514CD is shown as being comprised of algorithms, calculated values, and control output portions. In the algorithm portion, an operational algorithm is shown. In the calculated values portion, a density value, a mass flow rate ("MFR") and an accumulated MFR value are shown. The operational algorithm in the meter electronics 514CD calculates the density and mass flow rate values based on sensor signals from the concentrate sensor assembly 512CD. The meter electronics 514CD may therefore be viewed as performing core processing to determine, for example, measured fluid parameter values from which other values may be determined. The measured fluid parameter values are provided to the system computer 530.

The system computer 530 is shown as being comprised of a user input value(s) portion, an algorithm(s) portion, and a calculated value(s) portion. The user input value(s) includes a target amount of mixture and a target concentration, which are target values for the mixture. The algorithm(s) portion is shown as including a concentrate concentration determination software, batch target(s) software, batch operation, and a final concentration algorithm. The calculated value(s) portion is comprised of a concentrate concentration, a final concentration, a target amount of concentration and a target amount of dilutant.

The concentrate concentration determination software can determine a concentrate concentration value of the concentrate in the sensor assembly 512CD. It should be understood that the dilutant may be assumed to be 100 percent pure and therefore the system computer 530 does not include a concentration determination software or concentration values for the dilutant.

The batch operation algorithms in the system computer 530 may respectively control a MFR of the concentrate and the dilutant based on the target amount of concentrate and the target amount of dilutant. For example, the batch operation algorithm may control the operations of the concentrate supply 52C, dilutant supply 52D to meet the target amount of concentrate and the target amount of dilutant.

The batch target(s) software in the system computer 530 may calculate batch target values based on the target amount of mix and the target concentration value. For example, the batch target(s) software may receive the concentration value of the concentrate from the concentrate-dilutant flow meter 510CD and calculate an amount of the dilutant and the concentrate that would result in the mixture in the mixing tank 10T having the target amount of the mix and the target concentration.

The final concentration algorithm may calculate the actual concentration value of the mixture based on signals from the mixture concentration meter 140. The final concentration algorithm may be run after the mixing tank 10T is filled. However, it should be understood that the final concentration algorithm may be based on a general concentration algorithm that can be performed at any time in non-batching operations. Accordingly, the final concentration algorithm may be performed after a batch operation is run to determine the final concentration value.

The system computer 530 may compare the final concentration value with the target concentration value. If the final concentration value differs from the target concentration value, for example by more than a threshold amount, then another batching operation may be performed. Accordingly, the batch target(s) software may again calculate target batch values based on the target amount of mix and the target concentration as before but can also consider a difference between the final concentration and the target concentration. This correction batch operation may simply involve flowing a certain amount of dilute if the final concentration is too high and a certain amount of concentrate if the final concentration is too low.

<u>Fourth exemplary architecture</u>

**FIG. 7** shows a system 70 for two-source flow control for batch processing. The system 70 shown in FIG. 7 is similar to the system 50 shown in FIG. 5, except that the system 70 is configured to measure a concentration of concentrate-dilutant mixture. For example, in contrast to the system 50, the concentrate-dilutant flow meter 710CD may be configured to measure a density of the concentrate-dilutant mixture and determine a concentration of the concentrate-dilutant mixture using a two-component concentrate-

density array. The concentration of the concentrate-dilutant mixture measured by the concentrate-dilutant flow meter 710CD may be of the concentrate or the dilutant.

As shown in FIG. 7, the system 70 is comprised of a concentrate source 70C and a dilutant source 70D. The concentrate source 70C and dilutant source 70D are shown as being comprised of a concentrate supply 72C and dilutant supply 72D that are fluidly coupled to a flow meter system 700. The flow meter system 700 is fluidly coupled to the mixing tank 10T described above with reference to FIG. 1. The flow meter system 700 is comprised of a concentrate-dilutant flow meter 710CD that is fluidly coupled to the concentrate supply 72C and the dilutant supply 72D via the mixer 520 so as to receive a concentrate and a dilutant.

The concentrate-dilutant flow meter 710CD is also shown as being fluidly coupled to the mixing tank 10T. A valve is not between the concentrate-dilutant flow meter 710CD and the mixing tank 10T. Instead, the mixer 520 is between the concentrate-dilutant flow meter 710CD and the concentrate and dilutant supplies 72C, 72D. It should be appreciated that the mixer 520 may be used to mix two fluids together in the mixer 520 but can also receive and convey one of the concentrate and the dilutant respectively provided by the concentrate supply 52C and the dilutant supply 52D. That is, the concentrate and the dilutant may be provided to the concentrate-dilutant flow meter 510CD synchronously as a concentrate-dilutant mixture or asynchronously as separate concentrate and dilutant fluid flows.

The concentrate-dilutant flow meter 710CD is shown as being comprised of a sensor assembly 712CD and a meter electronics 714CD. The meter electronics 714CD is electrically coupled to the sensor assembly 712CD. The meter electronics 714CD may or may not be mechanically coupled to the sensor assembly 712CD. Similar to the meter electronics 514CD described above with reference to FIG. 5, the meter electronics 714CD is not communicatively coupled to the concentrate supply 72C and the dilutant supply 72D. Instead, the system computer 730 is communicatively coupled to the concentrate supply 72C and the dilutant supply 72D so as to control a supply of the concentrate and the dilutant. The meter electronics 714CD is also communicatively coupled, such as, for example, electrically coupled, to a system computer 730. The system computer 730 is also communicatively coupled to the mixture concentration meter 140 described above with reference to FIG. 1.

The meter electronics 714CD, system computer 730, concentrate supply 72C, dilutant supply 72D, and mixture concentration meter 140 may be communicatively coupled to each other in a manner similar to that described with reference to FIG. 5. The meter electronics 714CD may be configured to receive and/or provide signals to and/or from the sensor assembly 712CD to determine one or more fluid parameter values in a manner similar to the meter electronics 514CD described with reference to FIG. 5. The system computer 730 may be configured similar to the system computer 530 described with refence to FIG. 5.

As discussed above, the concentrate-dilutant flow meter 710CD shown in FIG. 7 may be configured to determine a concentration of the concentrate-dilutant mixture. More specifically, a table of values relating concentration with density may be stored in the meter electronics 714CD. Accordingly, a frequency of the concentration-density mixture in the concentrate-dilutant flow meter 710CD may be measured and compared to density values of the table to determine a concentration of one of the components in the concentrate-dilutant mixture. For example, the table may store the concentration values as a percentage of the concentrate. Other values may also be employed, such as temperature values, to determine the appropriate density values of the table. The concentration value of the concentrate-dilutant mixture in the concentrate-dilutant flow meter 710CD may be used in various ways, including controlling a flow rate of the concentrate and/or dilutant to ensure a correct concentration and volume, as the following explains in more detail.

**FIG. 8** shows a data processing schematic 800 of the flow meter system 700 for two-source flow control for batch processing described with reference to FIG. 7. As shown in FIG. 8, the data processing schematic 800 comprises the system computer 730 communicatively coupled to the meter electronics 714CD. As described above with reference to FIG. 7, the meter electronics 714CD is electrically coupled to the sensor assembly 712CD. The meter electronics 714CD is shown as being comprised of algorithms, calculated values, and control output portions. In the algorithm portion, an operational algorithm is shown. In the calculated values portion, a density value, a mass flow rate ("MFR") and an accumulated MFR value are shown. The operational algorithm in the meter electronics 714CD calculates the density and mass flow rate values based on sensor signals from the concentrate sensor assembly 712CD. The meter electronics 714CD may therefore be viewed as performing core processing to determine, for example, measured fluid parameter values from which other values may be determined. The measured fluid parameter values are provided to the system computer 730.

The system computer 730 is shown as being comprised of a user input value(s) portion, an algorithm(s) portion, and a calculated value(s) portion that include all of the algorithms and values described with reference to the system computer 530 of FIG. 5. Similar to the system computer 530 described with reference to FIG. 5, the system computer 730 may compare the final concentration value with the target concentration value. If the final concentration value differs from the target concentration value, for example by more than a threshold amount, then another batching operation may be performed. Accordingly, the batch target(s) software may again calculate target batch values based on the target amount of mix and the target concentration as before but can also consider a difference between the final concentration and the target concentration. This correction batch operation may simply involve flowing a certain amount of dilute if the final concentration is too high and a certain amount of concentrate if the final concentration is too low.

However, the system computer 730 may also flow the concentrate and the dilutant to achieve both the desired concentration and amount of the concentrate-dilutant mixture in the mixing tank 10T. That is, the foregoing Equations [1] and [2] may be used to determine an amount of concentration-dilutant mixture that should be added to the concentrate-dilutant mixture in the mixing tank 10T. In this case, the target amount of mixture $T_m$ of Equations [1] and [2] is a difference between the original target amount of mixture calculated for the first batching operation and an actual amount of concentrate-dilutant mixture. The actual amount of concentrate-dilutant mixture in the mixing tank 10T may be determined based on an accumulated flow rate of the concentrate-dilutant mixture measured by the concentrate-dilutant flow meter 710CD.

The concentration of the concentrate-dilutant mixture measured by the concentrate-dilutant flow meter 710CD can be adjusted during the flow of the batching operation. For example, if the concentration of the concentrate-density mixture at the concentrate-dilutant flow meter 710CD is less than a desired concentration of the mixture, such as a target mixture concentration, then the flow rate of the dilutant may be decreased and/or the flow rate of the concentrate may be increased. Conversely, if the concentration of the concentrate-density mixture at the concentrate-dilutant flow meter 710CD is greater than the desired concentration of the mixture, then the flow rate of the concentrate may be decreased and/or the flow rate of the dilutant may be increased. The adjustments may be made using, for example, a proportional-integral-differential (“PID”) controller in the meter electronics 714CD and/or system computer 730.

The amount of the concentrate-dilutant mixture of a first batching operation can also be controlled to undershoot the target amount of the concentrate-dilutant mixture in the mixing tank 10T. For example, if the concentration measured by the mixture concentration meter 140 is significantly less than the target concentration, then the amount of concentrate-dilutant mixture may be reduced. That is, an amount setpoint of the concentrate-dilutant mixture may be reduced to ensure that a sufficient amount of concentrate can be added to the concentrate-dilutant mixture in the mixing tank 10T during the correction batch operation. The difference between the amount setpoint and the target amount of the concentration-dilutant mixture may be determined based on Equation [3], for example.

More specifically, a continuously accumulated flow rate or a continuously calculated amount of the concentrate-dilutant mixture in the mixing tank 10T may be used as the amount of uncorrected mixture $T_m$ in Equation [3]. Similarly, a continuously calculated concentration of the concentrate-dilutant mixture in the concentrate-dilutant flow meter 710CD may be used as the concentration of the uncorrected mixture $C_m$ in Equation [3]. Accordingly, an amount of dilutant $T_d$ that should be added may be continually calculated. The continually calculated amount of dilutant $T_d$ that should be added may be used as constraints on the amount setpoint of the concentrate-dilutant mixture to ensure a sufficient undershoot for a subsequent correction batch. For example, a difference between the amount setpoint and the target amount of the concentrate-dilutant mixture may be constrained by a logical greater than the most positive value of the target amount of dilutant $T_d$ and the target amount of concentrate $T_c$ obtained using Equation [3].

As can be appreciated, because the concentrate-dilutant flow meter 710CD of FIG. 7 can also calculate a concentration of the concentrate-dilutant mixture in the concentrate-dilutant flow meter 710CD, Equation [4] may also be used in a similar manner. That is, a continually updated concentration of a concentrate in the concentrate-dilutant mixture measured by the concentrate-dilutant flow meter 710CD can be used as the initial amount of concentrate $T_{ci}$ in Equation [4]. The other values of Equation [4] can be obtained as described above with reference to Equation [3]. The amount of concentrate to be added may serve as a constraint on the difference between the amount setpoint and the target setpoint also as described above with reference to Equation [3]. As can be appreciated, both Equation [3] and Equation [4] may be employed. That is, the continually calculated amount of concentrate to be added according to Equation [4] and continually calculated amount of dilutant to be added according to Equation [3] may be compared to the difference between the continually calculated amount of concentrate-dilutant mixture as a constraint.

The comparison may also include a pipeline volume between the concentrate supply 72C and the dilutant supply 72D. For example, the pipeline volume may be added to the most positive number, or a sum of positive values (in the event of measurement errors), of the continually calculated amount of concentrate and amount of dilutant to be added. Accordingly, the difference between the continually calculated amount and target amount of concentrate-dilutant mixture may be constrained by both the amount of concentrate and/or dilutant required to obtain the target and amount of mixture in the mixing tank 10T, but also a volume of concentrate-dilutant mixture between the concentrate and dilutant supplies 72C, 72D and the mixing tank 10T.

The foregoing described features of the systems 10, 30, 50, 70 may be implemented using any suitable method. An exemplary method is described in the following.

Method for two-source flow control

**FIG. 9** shows a method 900 for two-source flow control for batch processing. As shown in FIG. 9, the method 900 in step 910 flows at least one of a concentrate and a dilutant into a mixing tank. In step 920, the method 900 measures and continuously accumulates a flow rate of at least one of the concentrate, the dilutant, and a concentrate-dilutant mixture. The method 900 discontinues the flow of the at least one of the concentrate, the dilutant, and the concentrate-dilutant mixture when the accumulated flow rate is equal to a desired total amount. The desired total amount may be a desired total amount of concentrate, dilutant, or concentrate-dilutant mixture. The flows of the concentrate, dilutant, and/or the concentrate dilutant mixture may or may not occur at the same time.

Flowing the concentrate and the dilutant into the mixing tank may comprise substantially synchronously flowing the concentrate and the dilutant into the mixing tank and substantially asynchronously flowing the concentrate and the dilutant into the mixing tank. For example, the concentrate and the dilutant may be flowed at the same time into a mixer or the mixing tank. If the concentrate and the dilutant are flowed into the mixer at the same time, then a concentrate-dilutant mixture may be flowed into the mixing tank. Synchronous flow refers to when the concentrate and the dilutant flow at the same time. Alternatively, the concentrate and the dilutant may be flowed at different times. The concentrate and the dilutant may be flowed at different times into a mixer or the mixing tank. Asynchronous flow refers to when the concentrate and the dilutant are flowed at different times. It should be appreciated that synchronous and asynchronous flow may occur in the same process. For example, a synchronous flow may be used for the main or initial batch processing whereas an asynchronous flow may be used for correction. It should also be appreciated that asynchronous flow may refer to when only one of the concentrate or the dilutant flows without a corresponding subsequent flow from the other.

As can be appreciated from the foregoing descriptions of the systems 10, 30, 50, 70, the flow rate of the concentrate may be measured by a concentrate flow meter or a concentrate-dilutant flow meter. Additionally, or alternatively, the flow rate of the dilutant may be measured by one of a dilutant flow meter and the concentrate-dilutant flow meter. Additionally, or alternatively, the flow rate of the concentrate-dilutant mixture may be measured by the concentrate-dilutant flow meter. The concentrate flow meter, dilutant flow meter, and/or the concentrate-dilutant flow meter used by the method 900 may respectively be the concentrate flow meter 110C, 310C, the dilutant flow meter 110D, 310D, and the concentrate-dilutant flow meter 510CD, 710CD described above, although any suitable flow meters may be employed.

The flow of the concentrate may be discontinued when the accumulated measured flow rate of the concentrate is equal to a desired total amount of concentrate. Additionally, or alternatively, the flow of the dilutant may be discontinued when the accumulated measured flow rate of the dilutant is equal to a desired total amount of dilutant. Additionally, or alternatively, the flow of the concentrate-dilutant mixture may be discontinued when the accumulated flow rate of the concentrate-dilutant mixture is equal to a desired total amount of concentrate-dilutant mixture. It should be appreciated that the flow of the concentrate, dilutant, and/or concentrate-dilutant mixture may be discontinued when an accumulated flow of another of the concentrate, dilutant, and/or concentrate-dilutant mixture equals a respective desired total amount. For example, a flow of the concentrate and a flow of the dilutant may be discontinued when the accumulated flow rate of the concentrate-dilutant mixture is equal to a desired total amount of concentrate-dilutant mixture. The method 900 may also obtain the desired total amount and continuously compare the desired total amount with the accumulated flow rate.

The desired total amount may or may not be the same as a target total amount. Accordingly, the desired total amount may be based on a target final concentration and a target final amount of the concentrate-dilutant mixture. For example, the desired total amount may be based on a target final concentration and a target final amount of mixture comprises the above-described Equations [1] and [2] although any suitable expression may be employed. It should be appreciated that the desired total amount may not be a value that is compared to the totalized amount of concentrate and dilutant. For example, a reference total amount of concentrate may be slightly less than the desired amount of concentrate to accommodate for, for example, a pipeline volume between the concentrate valve 120C and the mixing tank 10T. Accordingly, accumulating the measured flow rates of the concentrate and comparing the accumulated measured flow rate of the concentrate may comprise comparing a reference total amount of concentrate value to an accumulated measured flow rate value of the concentrate. If those two values are equal, then the concentrate valve 120C may be turned off.

Additionally, or alternatively, the method 900 may also comprise measuring a concentration of a mixture of the concentrate and the dilutant in the mixing tank and comparing the measured concentration with the target final concentration of the mixture. The concentration of the mixture may be measured by the mixture concentration meter 140 in the mixing tank 10T, although any suitable device may be employed, such as a Coriolis flow meter in a recirculating loop fluidly coupled to the mixing tank. Accordingly, the method 900 may compare the measured concentration of the mixture of the concentrate and the dilutant in the mixing tank with the target final concentration of the mixture.

This can allow the method 900 to add concentrate to the mixture of the concentrate and the dilutant in the mixing tank if the measured concentration is less than the target final concentration. For example, an amount of concentrate added to the mixture of the concentrate and the dilutant in the mixing tank may be determined according to the above Equation [4], although any suitable expression may be employed. Additionally, or alternatively, the method 900 may add dilutant to the mixture of the concentrate and the dilutant in the mixing tank if the measured concentration is greater than the target final concentration. For example, an amount of concentrate added to the mixture of the concentrate and the dilutant is determined using the above Equation [3], although any suitable expression or relationship may be employed.

System

The foregoing method 900 may be performed on the system 10, 30, 50, 70 described above. As described above, the system 10, 30, 50, 70 include the flow meter systems 100, 300, 500, 700 although any suitable flow meter systems may be employed. As can be appreciated from the foregoing discussion, the flow meter system 100, 300, 500, 700 configured to perform the method steps may comprise a concentrate flow meter 110C, 310C configured to measure the flow rate of the concentrate, a dilutant flow meter 110D, 310D configured to measure the flow rate of the dilutant, and a concentrate-dilutant flow meter 510CD, 710CD configured to measure the flow rate of the concentrate, the dilutant, and/or a concentrate-dilutant mixture, and a system computer 130, 330, 530, 730 communicatively coupled to the concentrate flow meter 110C, 310C, the dilutant flow meter 110D, 310D, and the concentrate-dilutant flow meter 510CD, 710CD.

At least one of the system computer 130, 330, 530, 730, the concentrate flow meter 110C, 310C, the dilutant flow meter 110D, 310D and the concentrate-dilutant flow meter 510CD, 710CD may be configured to execute the method 900 described above, although any suitable method may be employed. It should be appreciated that, in the flow meter system 100, 300, 500, 700, the concentrate flow meter 110C, 310C, the dilutant flow meter 110D, 310D, and the concentrate-dilutant flow meter 510CD, 710CD being configured to execute the method 900 described above, or portions thereof, may comprise the meter electronics 114C, 114D, 314, 514CD, 714CD being configured to execute the method 900, or portions thereof. Accordingly, a system 10, 30, 50, 70 for two-source flow control for batch processing can comprise a mixing tank 10T and the flow meter system 100, 300, 500, 700 fluidly coupled to the mixing tank 10T. The system 10, 30, 50, 70 may also comprise a concentrate supply 12C, 32C, 52C, 72C and a dilutant supply 12D, 32D, 52D, 72D fluidly coupled to the flow meter system 100, 300, 500, 700.

As described above, the systems 10, 30, 50, 70 include the concentrate flow meter 110C, 310C and the dilutant flow meter 110D, 310D, and the concentrate-dilutant flow meter 510CD, 710CD although any suitable flow meter may be employed. The following describes an exemplary flow meter that may be suitable for use as a concentrate flow meter similar to the concentrate flow meter 110C, 320C described above with reference to FIGS. 1 and 2.

## Exemplary flow meter

**FIG. 10** shows a vibratory meter 1005 configured for two-source flow control for batch processing. As shown in FIG. 10, the vibratory meter 1005 is a Coriolis flow meter that comprises a sensor assembly 1001 and meter electronics 1020. The vibratory meter 1005 is configured to perform the same algorithms and store the same values as concentrate flow meter 110C or dilutant flow meter 110D described above, although any suitable configuration may be employed. The sensor assembly 1001 responds to mass flow rate and density of a process material. The meter electronics 1020 is connected to the sensor assembly 1001 via leads 1010 to provide density, mass flow rate, and temperature information over path 1026, as well as other information, to a system computer, for example.

The sensor assembly 1001 includes a pair of manifolds 1015 and 1015', flanges 1011 and 1011' having flange necks, a pair of parallel conduits 1013 and 1013', driver 1018, resistive temperature detector (RTD) 1019, and a pair of pick-off sensors 1017l and 1017r. Conduits 1013 and 1013' have two essentially straight inlet legs and outlet legs, which converge towards each other at conduit mounting blocks 1012 and 1012'. The conduits 1013, 1013' bend at two symmetrical locations along their length and are essentially parallel throughout their length. Brace bars 1014 and 1014' serve to define the axis W and W' about which each conduit 1013, 1013' oscillates. The legs of the conduits 1013, 1013' are fixedly attached to conduit mounting blocks 1012 and 1012' and these blocks, in turn, are fixedly attached to manifolds 1015 and 1015'. This provides a continuous closed material path through sensor assembly 1001.

When flanges 1011 and 1011' connected into a process line (not shown) which carries the process material that is being measured, material enters the inlet end of the vibratory meter through an orifice in the flange 1011 and is conducted through the manifold 1015 to the conduit mounting block 1012 having a surface. Within the manifold 1015 the material is divided and routed through the conduits 1013, 1013'. Upon exiting the conduits 1013, 1013', the process material is recombined in a single stream within the block 1012' having a surface and the manifold 1015' and is thereafter routed to the outlet end connected by the flange 1011' to the process line (not shown).

The conduits 1013, 1013' are selected and appropriately mounted to the conduit mounting blocks 1012, 1012' so as to have substantially the same mass distribution, moments of inertia and Young's modulus about bending axes W--W and W'--W', respectively. These bending axes go through the brace bars 1014, 1014'. Inasmuch as the Young's modulus of the conduits change with temperature, and this change affects the calculation of flow and density, RTD 1019 is mounted to conduit 1013' to continuously measure the temperature of the conduit 1013'. The temperature of the conduit 1013' and hence the voltage appearing across the RTD 1019 for a given current passing therethrough is governed by the temperature of the material passing through the conduit 1013'. The temperature dependent voltage appearing across the RTD 1019 is used in a well-known method by the meter electronics 1020 to compensate for the change in elastic modulus of the conduits 1013, 1013' due to any changes in conduit temperature. The RTD 1019 is connected to the meter electronics 1020 by a lead.

Both of the conduits 1013, 1013' are driven by driver 1018 in opposite directions about their respective bending axes W and W' and at what is termed the first out-of-phase bending mode of the vibratory meter. This driver 1018 may comprise any one of many well-known arrangements, such as a magnet mounted to the conduit 1013' and an opposing coil mounted to the conduit 1013 and through which an alternating current is passed for vibrating both conduits 1013, 1013'. A suitable drive signal is applied by the meter electronics 1020, via a lead, to the driver 1018.

The meter electronics 1020 receives the RTD 1019, and sensor signals appearing on leads 1010 carrying left and right sensor signals, respectively. The meter electronics 1020 produces the drive signal appearing on the lead to driver 1018 and vibrate conduits 1013, 1013'. The meter electronics 1020 processes the left and right sensor signals and the RTD 1019 to compute the mass flow rate and the density of the material passing through sensor assembly 1001. This information, along with other information, is applied by meter electronics 1020 over path 1026 as a signal.

A mass flow rate measurement can be generated according to the following relationship:

$$\dot{m} = FCF[\Delta t - \Delta t_0]; \qquad \text{Equation [5]}$$

where:

$\dot{m}$ is a measured mass flow rate;

$FCF$ is a flow calibration factor;

$\Delta t$ is a measured time-difference; and

$\Delta t_0$ is a zero-flow time-difference.

The measured time-difference $\Delta t$ comprises an operationally derived (i.e., measured) time-difference value comprising the time-difference existing between the pickoff sensor signals, such as where the time-difference is due to Coriolis effects related to mass flow rate through the vibratory meter 1005. The measured time-difference $\Delta t$ is a direct measurement of a mass flow rate of the flow material as it flows through the vibratory meter 1005. The zero-flow time-difference $\Delta t_0$ comprises a time-difference at a zero flow. The zero-flow time-difference $\Delta t_0$ is a zero-flow value that may be determined at the factory and programmed into the vibratory meter 1005. The zero-flow time-difference $\Delta t_0$ is an exemplary zero-flow value. Other zero-flow values may be employed, such as a phase difference, time-difference, or the like, that are determined at zero flow conditions. A value of the zero-flow time-difference $\Delta t_0$ may not change, even where flow conditions are changing. A mass flow rate value of the material flowing through the vibratory meter 1005 is determined by multiplying a difference between measured time-difference $\Delta t$ and a reference zero-flow value $\Delta t_0$ by the flow calibration factor *FCF*. The flow calibration factor *FCF* is proportional to a physical stiffness of the vibratory meter.

As to density, a resonance frequency at which each conduit 1013, 1013' vibrates may be a function of the square root of a spring constant of the conduit 1013, 1013' divided by the total mass of the conduit 1013, 1013' having a material. The total mass of the conduit 1013, 1013' having the material may be a mass of the conduit 1013, 1013' plus a mass of a material inside the conduit 1013, 1013'. The mass of the material in the conduit 1013, 1013' is directly proportional to the density of the material. Therefore, the density of this material may be proportional to the square of a period at which the conduit 1013, 1013' containing the material oscillates multiplied by the spring constant of the conduit 1013, 1013'. Hence, by determining the period at which the conduit 1013, 1013' oscillates and by appropriately scaling the result, an accurate measure of the density of the material contained by the conduit 1013, 1013' can be obtained. The meter electronics 1020 can determine the period or resonance frequency using the sensor signals and/or the drive signal. The conduits 1013, 1013' may oscillate with more than one vibration mode.

The vibratory meter 1005 may be calibrated with a factory zero-flow value while the vibratory meter 1005 is in a no or zero-flow condition. A user, at any time, may additionally, and optionally, perform a push-button calibration to obtain a push-button zero-flow value. Additionally, or alternatively, the vibratory meter may automatically perform a calibration to obtain an automatic zero-flow value. The zero-flow value used to measure a flow rate of a fluid may be the factory zero-flow value, a push-button zero-flow value, the automatic zero-flow value, or any other suitable zero-flow value.

Measurements, saved values/constants, user settings, saved tables, etc., may be employed during the zero calibration of the vibratory meter 1005. The calibration may monitor the vibratory meter 1005 for conditions of the vibratory meter 1005 and compensate for those conditions. The conditions may include user-input conditions, measured conditions, inferred conditions, or the like, without limitation. The conditions may include temperature, fluid density, flow rate, meter specifications, viscosity, Reynold's number, post calibration compensation, etc. In addition, different constants, such as a flow calibration factor (FCF), for example without limitation, may be applied based on operating conditions or user preference.

An initial zero-flow value may be determined during a calibration conducted as part of the initial factory setup of the vibratory meter 1005. This may entail placing the vibratory meter 1005 in a no or zero-flow condition and determining a time-difference, phase difference, or the like, between the left and right sensor signals. The determined value is stored in one or more memories as the initial zero-flow value and used as a reference zero-flow value. By way of example, for Equation [5] discussed above, the reference zero-flow value may be the $\Delta T_0$ term, which may be a no or zero-flow time-difference between the left and right sensor signals. Once the reference zero-flow value is determined, the flow calibration factor (FCF) may be established, which, as can be appreciated from above Equation [5], may be a slope of a line that dictates the relationship between the measured time-difference $\Delta t_{measured}$ and the mass flow rate $\dot{m}$. The FCF may be stored in the one or more memories.

**FIG. 11** shows a meter electronics 1020 configured for two-source flow control for batch processing. As shown in FIG. 11, the meter electronics 1020 includes an interface 1021 and a processing system 1022. The meter electronics 1020 receives a vibrational response from a sensor assembly, such as the sensor assembly 1001, for example. The meter electronics 1020 processes the vibrational response in order to obtain flow properties of the flow material flowing through the sensor assembly 1001. The meter electronics 1020 may also perform checks, verifications, calibration routines, or the like, to ensure the flow properties of the flow material are accurately measured.

The interface 1021 may receive the sensor signals from one of the pick-off sensors 1017l, 1017r shown in FIG. 10. The interface 1021 can perform any necessary or desired signal conditioning, such as any manner of formatting, amplification, buffering, etc. Alternatively, some or all of the signal conditioning can be performed in the processing system 1022. In addition, the interface 1021 can enable communications between the meter electronics 1020 and external devices. The interface 1021 can be capable of any manner of electronic, optical, or wireless communication. The interface 1021 can provide information based on the vibrational response. The interface 1021 may be coupled with a digitizer, such as a coder/decoder (CODEC), wherein the sensor signal comprises an analog sensor signal. The digitizer samples and digitizes an analog sensor signal and produces a digitized sensor signal.

The processing system 1022 conducts operations of the meter electronics 1020 and processes flow measurements from the sensor assembly 1001. The processing system 1022 executes one or more processing routines and thereby processes the flow measurements in order to produce one or more flow properties. The processing system 1022 is communicatively coupled to the interface 1021 and is configured to receive the information from the interface 1021.

The processing system 1022 can comprise a general-purpose computer, a micro-processing system, a logic circuit, or some other general purpose or customized processing device. Additionally, or alternatively, the processing system 1022 can be distributed among multiple processing devices. The processing system 1022 can also include any manner of integral or independent electronic storage medium, such as the storage system 1024.

The storage system 1024 can store vibratory meter parameters and data, software routines, constant values, and variable values. In one embodiment, the storage system 1024 includes routines that are executed by the processing system 1022, such as an operational routine 1024a, calibration routine 1024b and mass flow rate routine 1024c of the vibratory meter 1005. The storage system 1024 can store values that are used in the routines, such as temperature correction, calibration, zero offset, etc. The storage system 1024 can also store other types of values, such as statistical values, such as a mean, standard deviation, confidence interval, etc., or the like of the various value discussed herein. The storage system 1024 can also store values in table format where each row in the table corresponds to a sample of time series, such as a time series of parameter data.

For the vibratory meter 1005 described above, the operational routine 1024a may employ the sensor signals received by the interface 1021 to calculate a density value. For example, the sensor signals from one of the pick-off sensors 1017l, 1017r may be employed to determine the resonance frequency at each conduit 1013, 1013'. The resonance frequency can be used to determine a density value 1024d. The calibration routine 1024b may perform a zero verification, a flow calibration factor ("FCF") determination, and/or a mass flow rate error relationship determination and/or correction described above, although any suitable calibration routines may be employed. The calibration routine 1024b may determine the FCF 1024g.

The mass flow rate routine 1024c may determine a mass flow rate value 1024e based on the sensor signals received by the interface 1021. The mass flow rate value 1024e may be determined from the sensor signals, such as a time delay 1024f between a left pickoff sensor signal and a right pickoff sensor signal, and the FCF 1024g value.

Also shown is a concentrate concentration determination 1024h algorithm and batch operation 1024i software, which are described above with reference to FIGS. 1 and 2. These can be used to determine a concentrate concentration 1024j and accumulated MFR 1024k values. Batch target values may also be stored, such as the concentrate batch target 1024l. The accumulated MFR 1024k may be compared by the processing system 1022 to the concentrate batch target 1024l amount, adjusted or not by an AOC, to determine if the flow of the concentrate should be stopped.

As described above, the flow meter system 100, system 10, 30, 50, 70 and method 900 can perform two-source flow control for batch processing. That is, by flowing the concentrate and dilutant and continuously measuring and accumulating the flow rates of the concentrate and dilutant in a batch process while the concentrate and dilutant are flowing, the flow may continue uninterrupted. In addition, continuously comparing the measured and accumulated flow rates of the concentrate, dilutant, and/or concentrate-dilutant mixture to the desired amounts of concentrate, dilutant, and/or concentrate-dilutant mixture can ensure that an accurate amount of the concentrate and dilutant is dispensed into the mixing tank.

In addition, measuring and comparing the concentration of the mixture in the mixing tank to the desired concentration of the mixture can allow for automated correction batches. For example, if the measured concentration is less than the desired concentration, then a small amount of concentrate may be dispensed into the mixing tank. Alternatively, if the measured concentration is greater than the desired concentration, then a small amount of dilutant may be dispensed into the mixing tank. The foregoing corrective batches may be automatically initiated and performed. Similarly, a difference between a continually accumulated amount of concentrate-dilutant mixture and the target amount of concentrate-dilutant mixture can be compared to an amount of concentrate and/or dilutant to be added to the mixture to ensure sufficient undershoot of the amount of mixture in the mixing tank 10T. Accordingly, a subsequent correction batch can achieve both the target amount and concentration of the mixture in the mixing tank 10T.

The detailed descriptions of the above embodiments are not exhaustive descriptions of all embodiments contemplated by the inventors to be within the scope of the present description. Indeed, persons skilled in the art will recognize that certain elements of the above-described embodiments may variously be combined or eliminated to create further embodiments, and such further embodiments fall within the scope and teachings of the present description. It will also be apparent to those of ordinary skill in the art that the above-described embodiments may be combined in whole or in part to create additional embodiments within the scope and teachings of the present description.

Thus, although specific embodiments are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the present description, as those skilled in the relevant art will recognize. The teachings provided herein can be applied to other two-source flow control systems for batch processing and not just to the embodiments described above and shown in the accompanying figures. Accordingly, the scope of the embodiments described above should be determined from the following claims.

We claim:

1. A method of two-source flow control for batch processing, the method comprising:

flowing at least one of a concentrate and a dilutant into a mixing tank;

measuring and continuously accumulating a flow rate of at least one of the concentrate, the dilutant, and a concentrate-dilutant mixture; and

discontinuing the flow of the at least one of the concentrate, the dilutant, and the concentrate-dilutant mixture when the accumulated flow rate is equal to a desired total amount.

2. The method of claim 1, wherein discontinuing the flow when the accumulated flow rate is equal to the desired total amount comprises at least one of:

discontinuing the flow of the concentrate when the accumulated measured flow rate of the concentrate is equal to a desired total amount of concentrate;

discontinuing the flow of the dilutant when the accumulated measured flow rate of the dilutant is equal to a desired total amount of dilutant; and

discontinuing the flow of the concentrate-dilutant mixture when the accumulated flow rate of the concentrate-dilutant mixture is equal to a desired total amount of concentrate-dilutant mixture.

3. The method of claim 1, wherein:

the flow rate of the concentrate is measured by one of a concentrate flow meter and a concentrate-dilutant flow meter:

the flow rate of the dilutant is measured by one of a dilutant flow meter and the concentrate-dilutant flow meter; and

the flow rate of the concentrate-dilutant mixture is measured by the concentrate-dilutant flow meter.

4. The method of claim 1, wherein flowing the concentrate and the dilutant into the mixing tank comprises one of:

substantially synchronously flowing the concentrate and the dilutant into the mixing tank; and substantially asynchronously flowing the concentrate and the dilutant into the mixing tank.

5. The method of claim 4, wherein substantially synchronously flowing the concentrate and the dilutant into the mixing tank comprises mixing the concentrate and the dilutant and flowing the concentrate-dilutant mixture into the mixing tank.

6. The method of claim 1, wherein continuously accumulating the measured flow rate comprises continuously accumulating with respect to time the measured flow rate.

7. The method of claim 1, further comprising:
obtaining the desired total amount; and
continuously comparing the desired total amount with the accumulated flow rate.

8. The method of claim 1, wherein the desired total amount is based on a target final concentration and a target final amount of the concentrate-dilutant mixture.

9. The method of claim 8, wherein the desired total amount being based on the target final concentration and the target final amount of the concentrate-dilutant mixture comprises:

$$T_c = T_m \times \frac{C_t}{C_c}; \text{ and}$$

$$T_d = T_m - T_c;$$

where:

$T_c$= total amount of concentrate;

$T_d$= total amount of dilutant;

$T_m$= target amount of concentrate-dilutant mixture;

$C_t$= target final concentration; and

$C_c$= concentration of raw concentrate.

10. The method of one or claims 8 or 9, further comprising:

measuring a concentration of the concentrate-dilutant mixture in the mixing tank; and

comparing the measured concentration with the target final concentration of the concentrate-dilutant mixture.

11. The method of claim 10, further comprising adding concentrate to the concentrate-dilutant mixture in the mixing tank if the measured concentration is less than the target final concentration.

12. The method of claim 11, wherein an amount of concentrate added to the concentrate-dilutant mixture in the mixing tank is determined according to the following relationship:

$$T_c = \frac{(C_t T_m - C_c T_{ci})}{C_c - C_t};$$

$T_c$ =amount of concentrate to be added for correction;

$T_{ci}$= initial amount of raw concentrate used for an uncorrected mixture;

$C_t$= correct (original target) concentration;

$T_m$= amount of uncorrected concentrate-dilutant mixture; and

$C_c$= concentration of raw concentrate.

13. The method of claim 12, further comprising adding dilutant to the concentrate-dilutant mixture in the mixing tank if the measured concentration is greater than the target final concentration.

14. The method of claim 13, wherein the amount of dilutant added to the mixture of the concentrate and the dilutant is determined using the following relationship:

$$T_d = T_m \left( \frac{C_m}{C_t} - 1 \right);$$

where:

$T_d$ = amount of dilutant to be added for correction;

$C_m$ = concentration of uncorrected concentrate-dilutant mixture;

$C_t$ = correct (original target) concentration; and

$T_m$= amount of uncorrected concentrate-dilutant mixture.

15. A flow meter system (100, 300, 500, 700) for two-source flow control for batch processing, the flow meter system (100, 300, 500, 700) comprising:

one of:

a concentrate flow meter (110C, 310C) configured to measure a flow rate of a concentrate and a dilutant flow meter (110D, 310D) configured to measure a flow rate of a dilutant; and

a concentrate-dilutant flow meter (510CD, 710CD) configured to measure at least one of the flow rate of the concentrate, the flow rate of the dilutant, and a flow rate of the concentrate-dilutant mixture; and

a system computer (130, 330, 530, 730) communicatively coupled to the one of:

the concentrate flow meter (110C, 310C) and the dilutant flow meter (110D, 310D); and

the concentrate-dilutant flow meter (510CD, 710CD);

wherein at least one of the system computer (130, 330, 530, 730) and the one of the concentrate flow meter (110C, 310C) and the dilutant flow meter (110D, 310D) and the concentrate-dilutant flow meter (510CD, 710CD) is configured to execute the method according to at least one of the foregoing claims 1 through 14.

16. The flow meter system (100, 300, 500, 700) of claim 15, wherein at least one of the concentrate flow meter (110C, 310C), the dilutant flow meter (110D, 310D), and the concentrate-dilutant flow meter (510CD, 710CD) being configured to execute the method of at least one of the foregoing claims 1 through 14 comprises a meter electronics (114C, 114D, 314, 514CD, 714CD) configured to execute the method according to at least one of the foregoing claims 1 through 14.

17. A system (10, 30, 50, 70) for two-source flow control for batch processing, the system (10, 30, 50, 70) comprising:

a mixing tank (10T); and

the flow meter system (100, 300, 500, 700) according to one of claim 15 or claim 16 fluidly coupled to the mixing tank (10T).

18. The system (10, 30, 50, 70) of claim 17, further comprising a concentrate supply (12C, 32C, 52C, 72C) and a dilutant supply (12D, 32D, 52D, 72D) fluidly coupled to the flow meter system (100, 300, 500, 700).

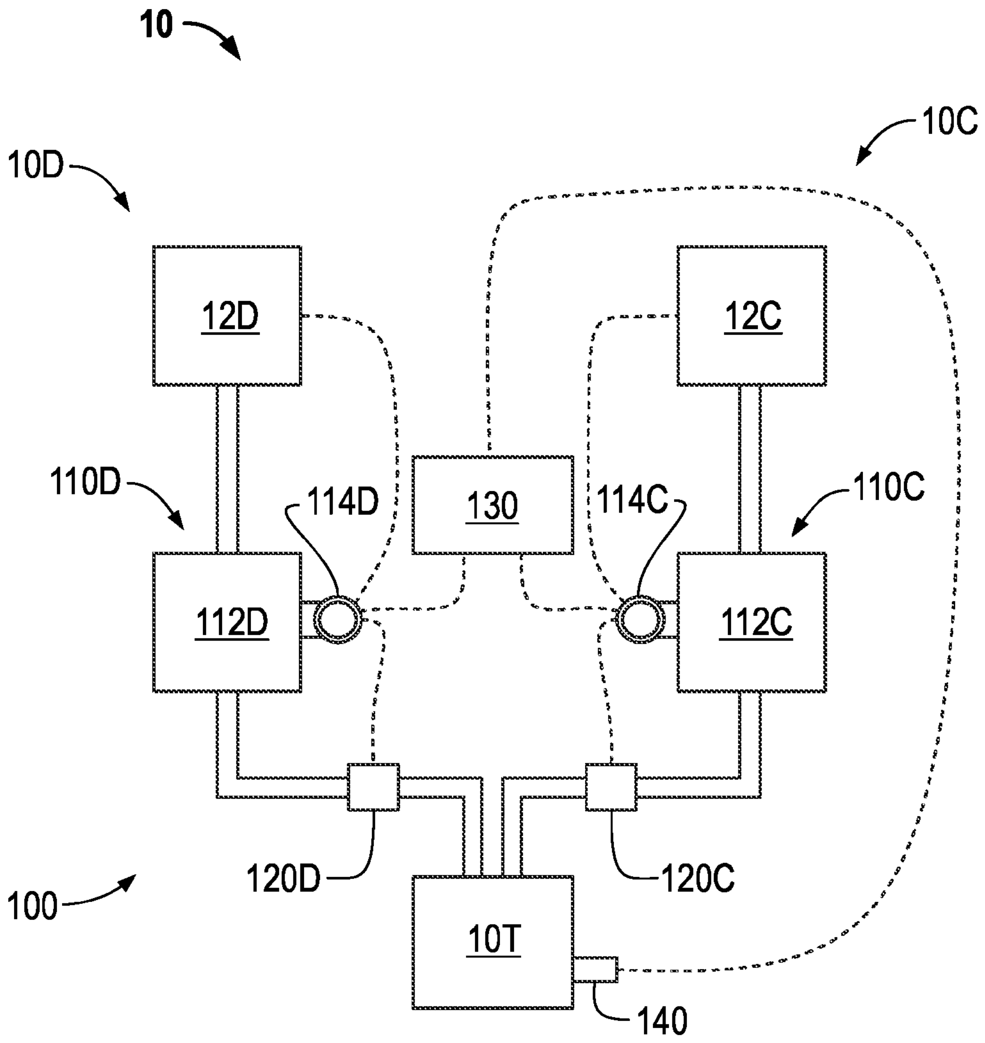

10
10D
10C
12D
12C
110D
114D
130
114C
110C
112D
112C
120D
120C
100
10T
140

FIG. 1

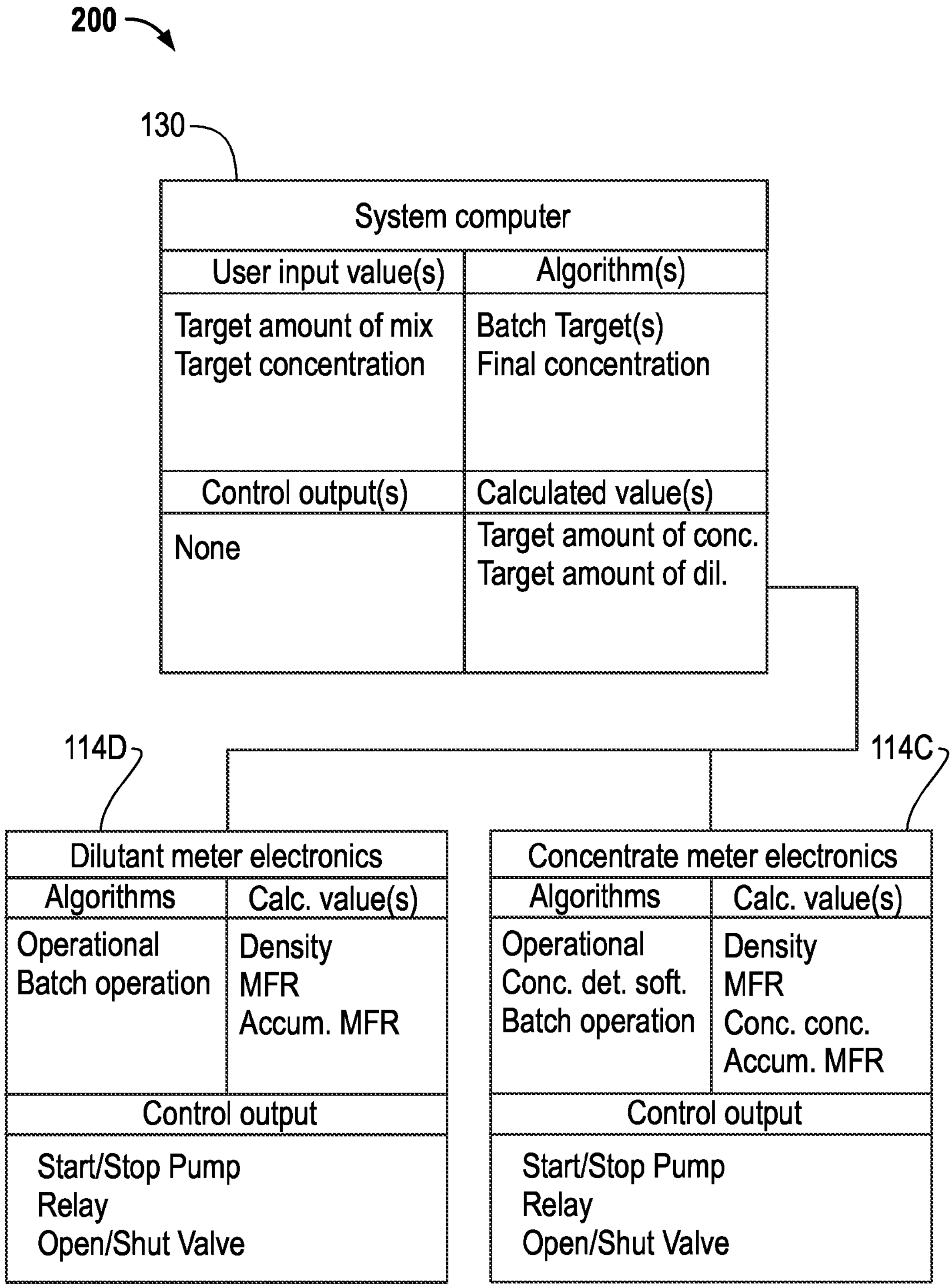

200
130
System computer
User input value(s)
Algorithm(s)
Target amount of mix
Target concentration
Batch Target(s)
Final concentration
Control output(s)
Calculated value(s)
None
Target amount of conc.
Target amount of dil.
114D
114C
Dilutant meter electronics
Algorithms
Calc. value(s)
Operational
Batch operation
Density
MFR
Accum. MFR
Control output
Start/Stop Pump
Relay
Open/Shut Valve
Concentrate meter electronics
Algorithms
Calc. value(s)
Operational
Conc. det. soft.
Batch operation
Density
MFR
Conc. conc.
Accum. MFR
Control output
Start/Stop Pump
Relay
Open/Shut Valve

FIG. 2

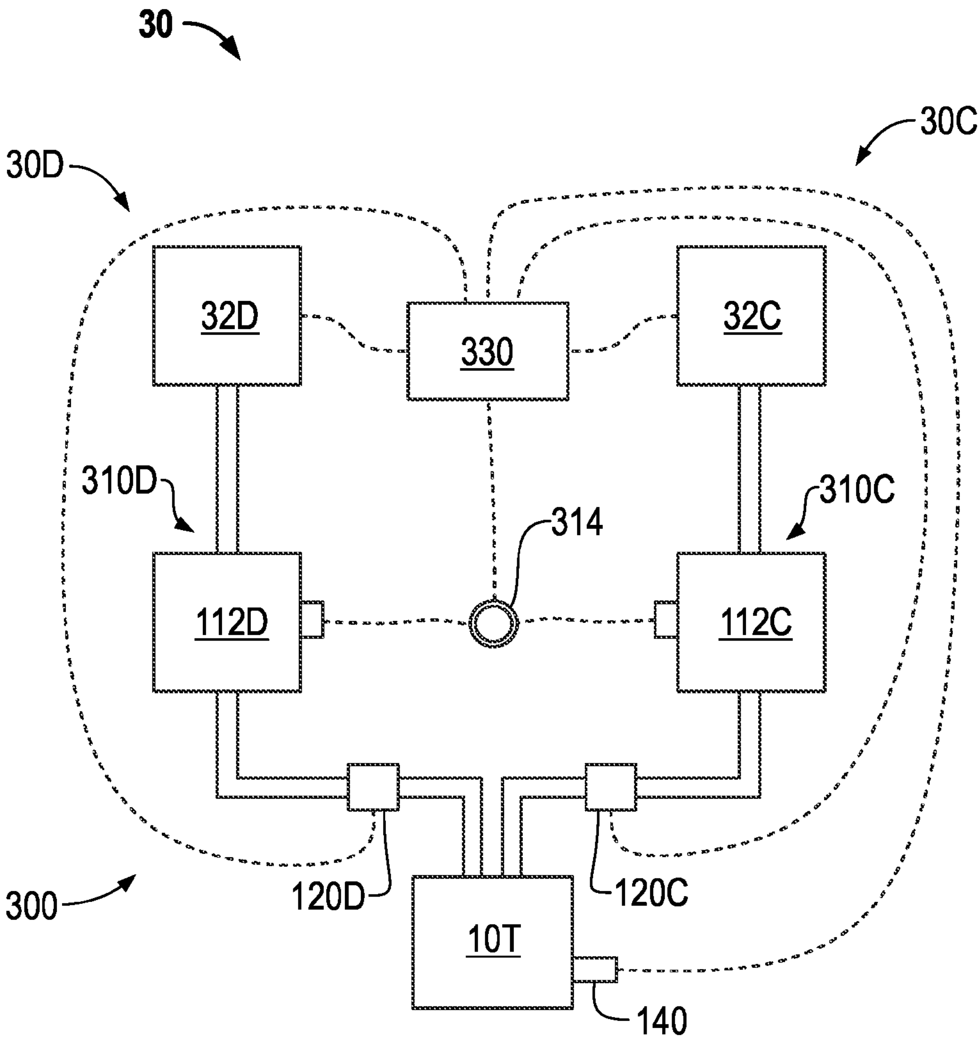

30
30D
30C
32D
330
32C
310D
310C
314
112D
112C
300
120D
120C
10T
140

FIG. 3

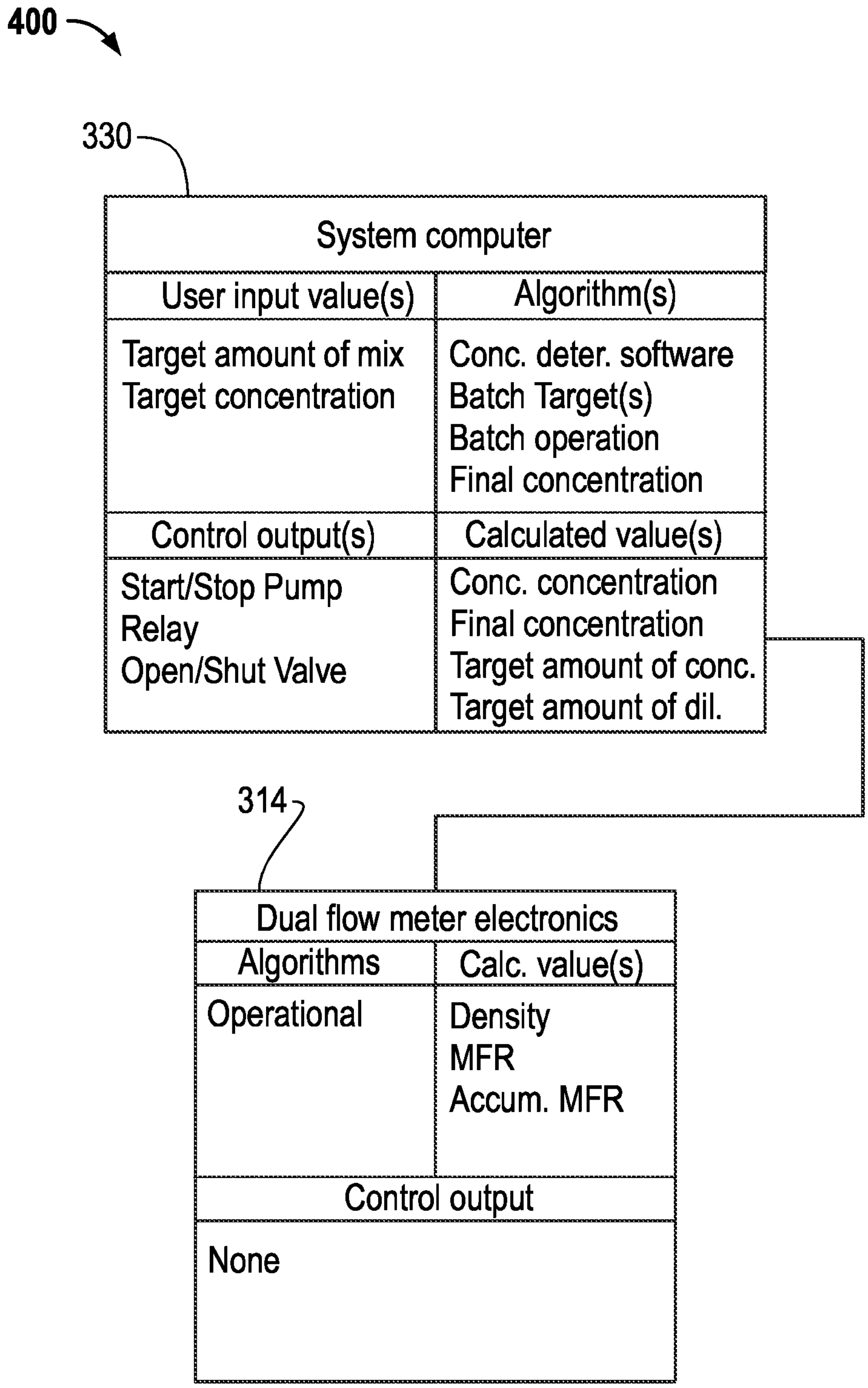

400
330
System computer
User input value(s)
Algorithm(s)
Target amount of mix
Target concentration
Conc. deter. software
Batch Target(s)
Batch operation
Final concentration
Control output(s)
Calculated value(s)
Start/Stop Pump
Relay
Open/Shut Valve
Conc. concentration
Final concentration
Target amount of conc.
Target amount of dil.
314
Dual flow meter electronics
Algorithms
Calc. value(s)
Operational
Density
MFR
Accum. MFR
Control output
None

FIG. 4

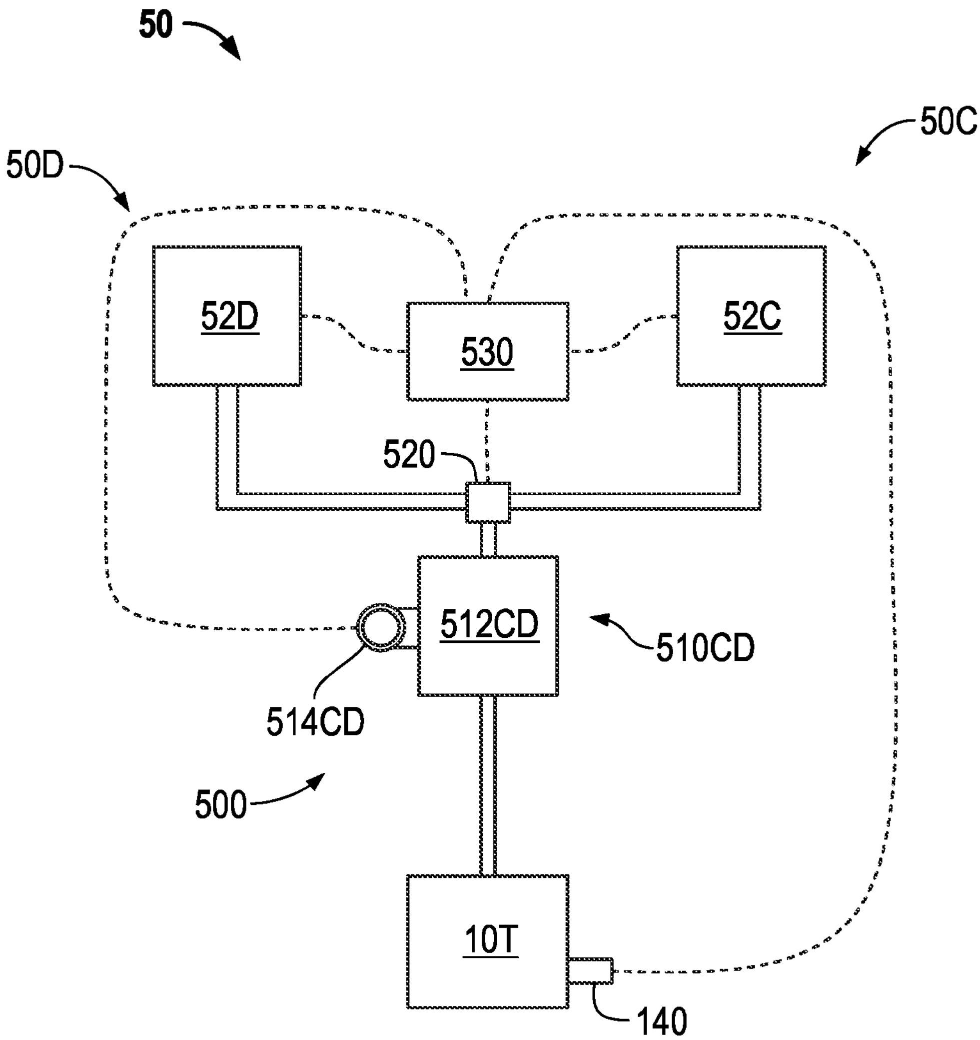



FIG. 5

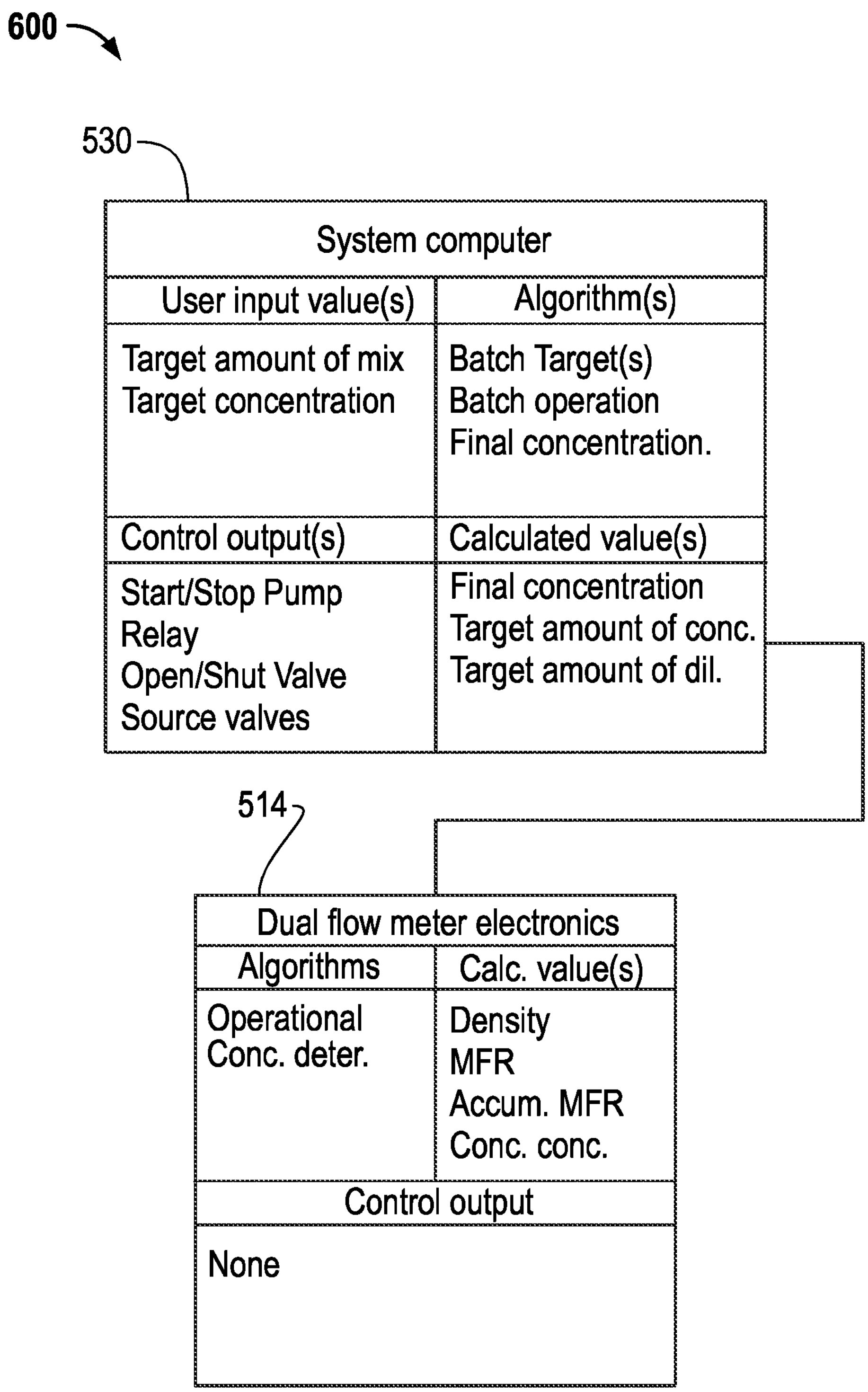

600
530
System computer
User input value(s)
Algorithm(s)
Target amount of mix
Target concentration
Batch Target(s)
Batch operation
Final concentration.
Control output(s)
Calculated value(s)
Start/Stop Pump
Relay
Open/Shut Valve
Source valves
Final concentration
Target amount of conc.
Target amount of dil.
514
Dual flow meter electronics
Algorithms
Calc. value(s)
Operational
Conc. deter.
Density
MFR
Accum. MFR
Conc. conc.
Control output
None

FIG. 6

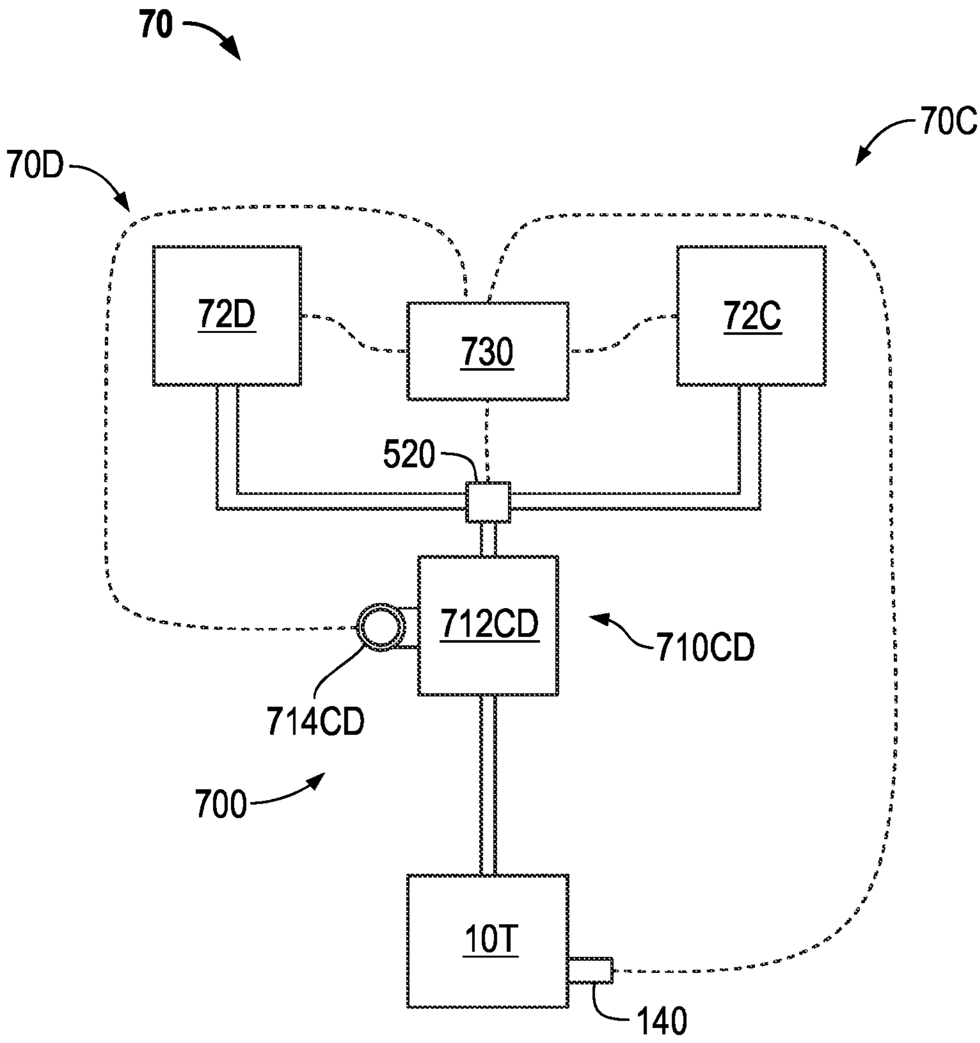



FIG. 7

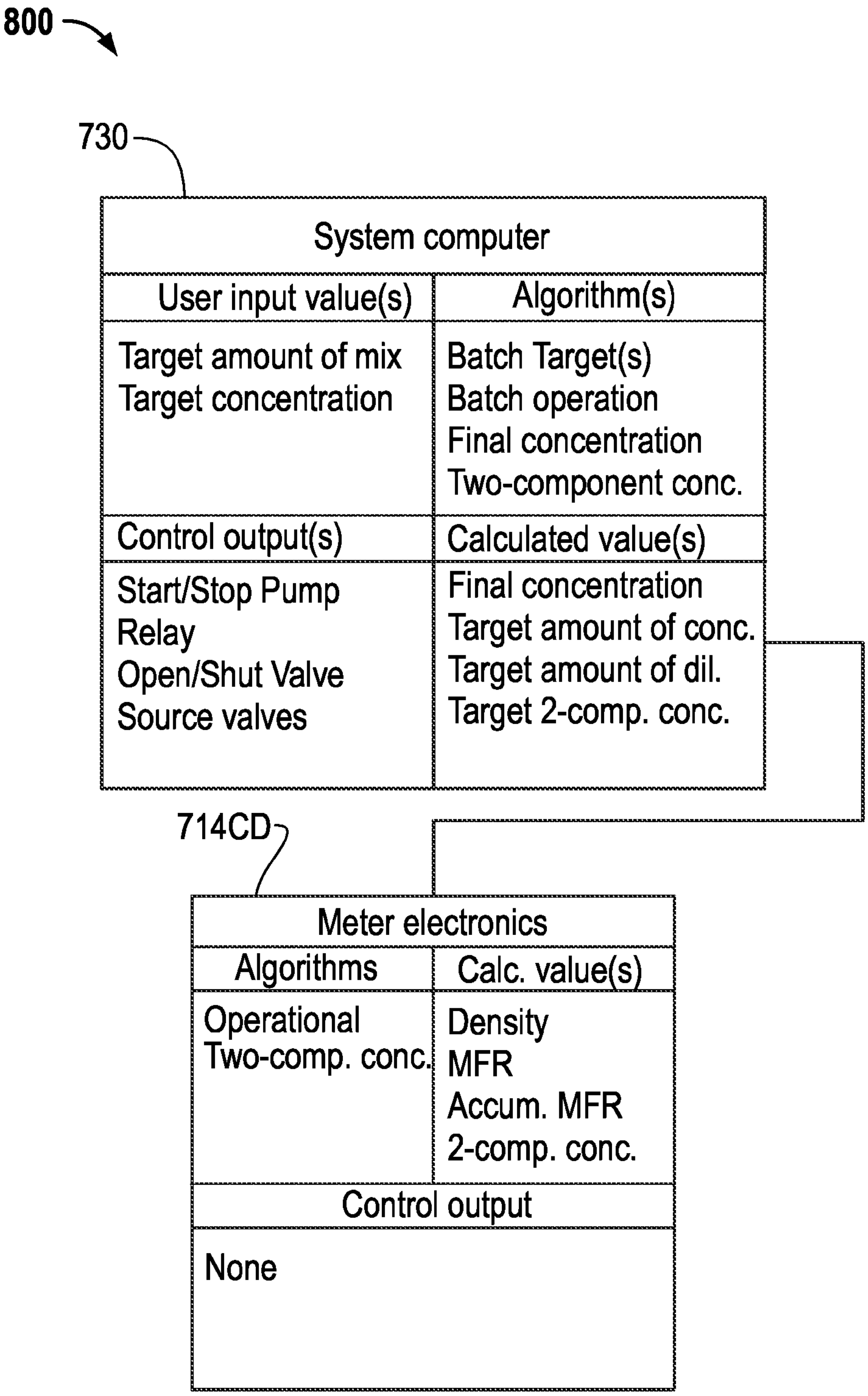

800
730
System computer
User input value(s)
Algorithm(s)
Target amount of mix
Target concentration
Batch Target(s)
Batch operation
Final concentration
Two-component conc.
Control output(s)
Calculated value(s)
Start/Stop Pump
Relay
Open/Shut Valve
Source valves
Final concentration
Target amount of conc.
Target amount of dil.
Target 2-comp. conc.
714CD
Meter electronics
Algorithms
Calc. value(s)
Operational
Two-comp. conc.
Density
MFR
Accum. MFR
2-comp. conc.
Control output
None

FIG. 8

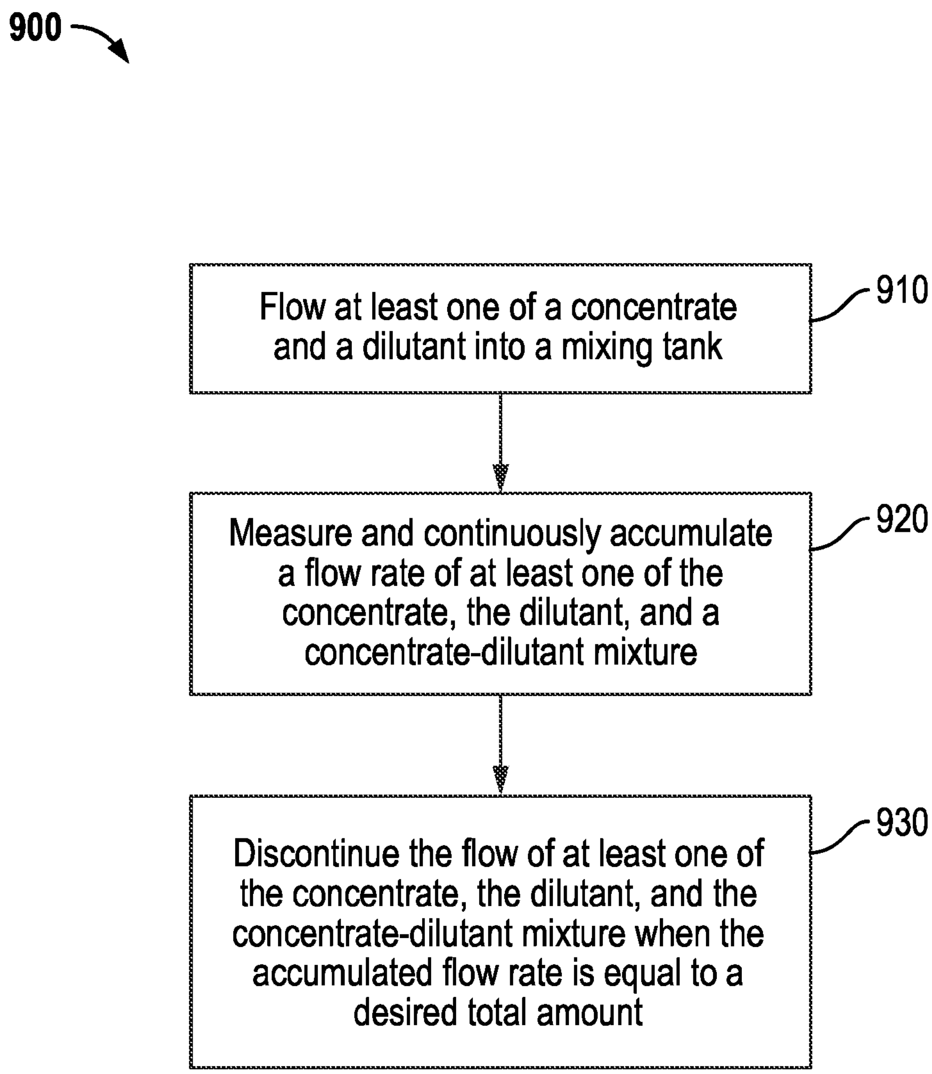
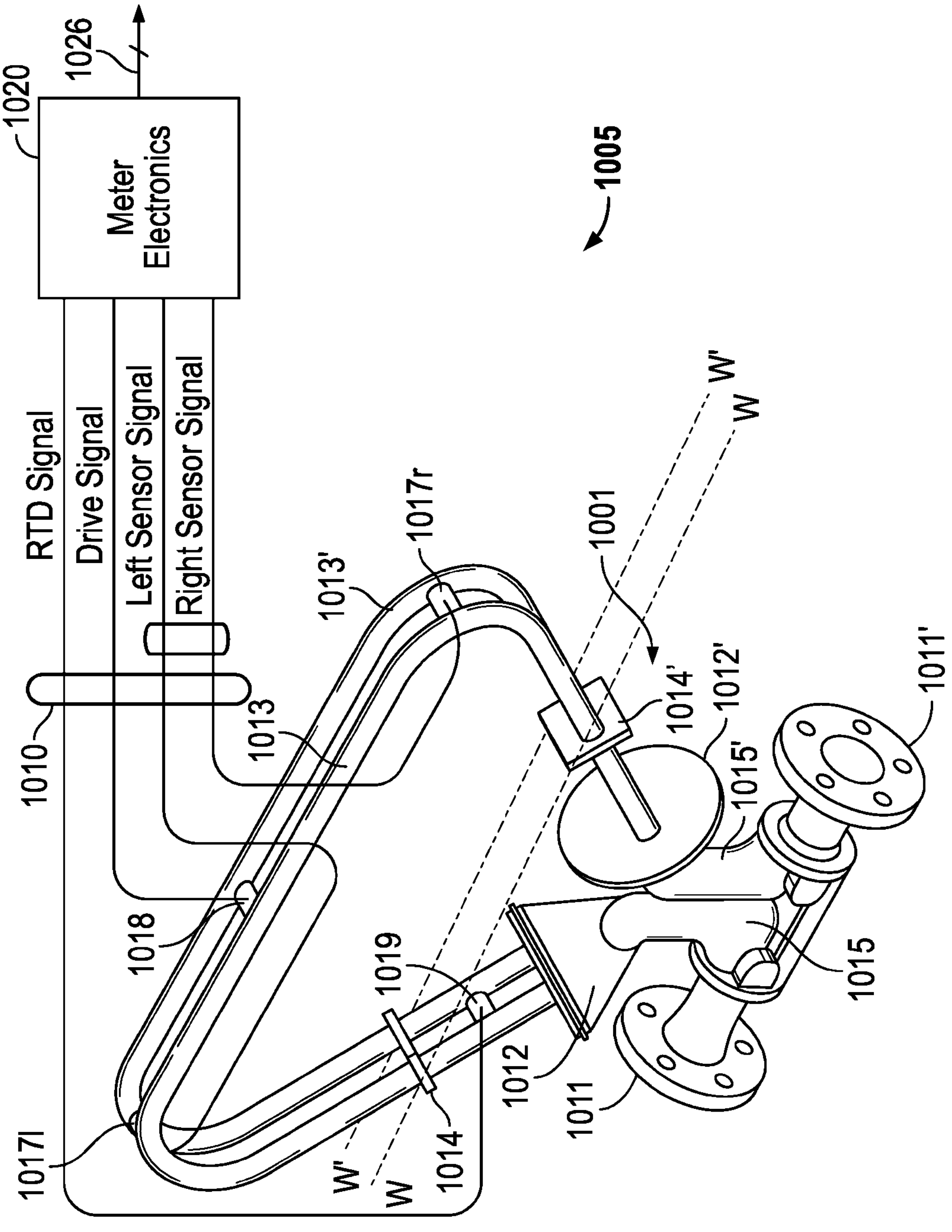

900
Flow at least one of a concentrate and a dilutant into a mixing tank
910
Measure and continuously accumulate a flow rate of at least one of the concentrate, the dilutant, and a concentrate-dilutant mixture
920
Discontinue the flow of at least one of the concentrate, the dilutant, and the concentrate-dilutant mixture when the accumulated flow rate is equal to a desired total amount
930

FIG. 9



1020
1026
Meter Electronics
1005
RTD Signal
Drive Signal
Left Sensor Signal
Right Sensor Signal
1010
1018
1017l
1013
1013'
1017r
1001
W'
W
1014'
1012'
1015'
1011'
1015
1019
1012
1011
1014
W'
W


FIG. 10

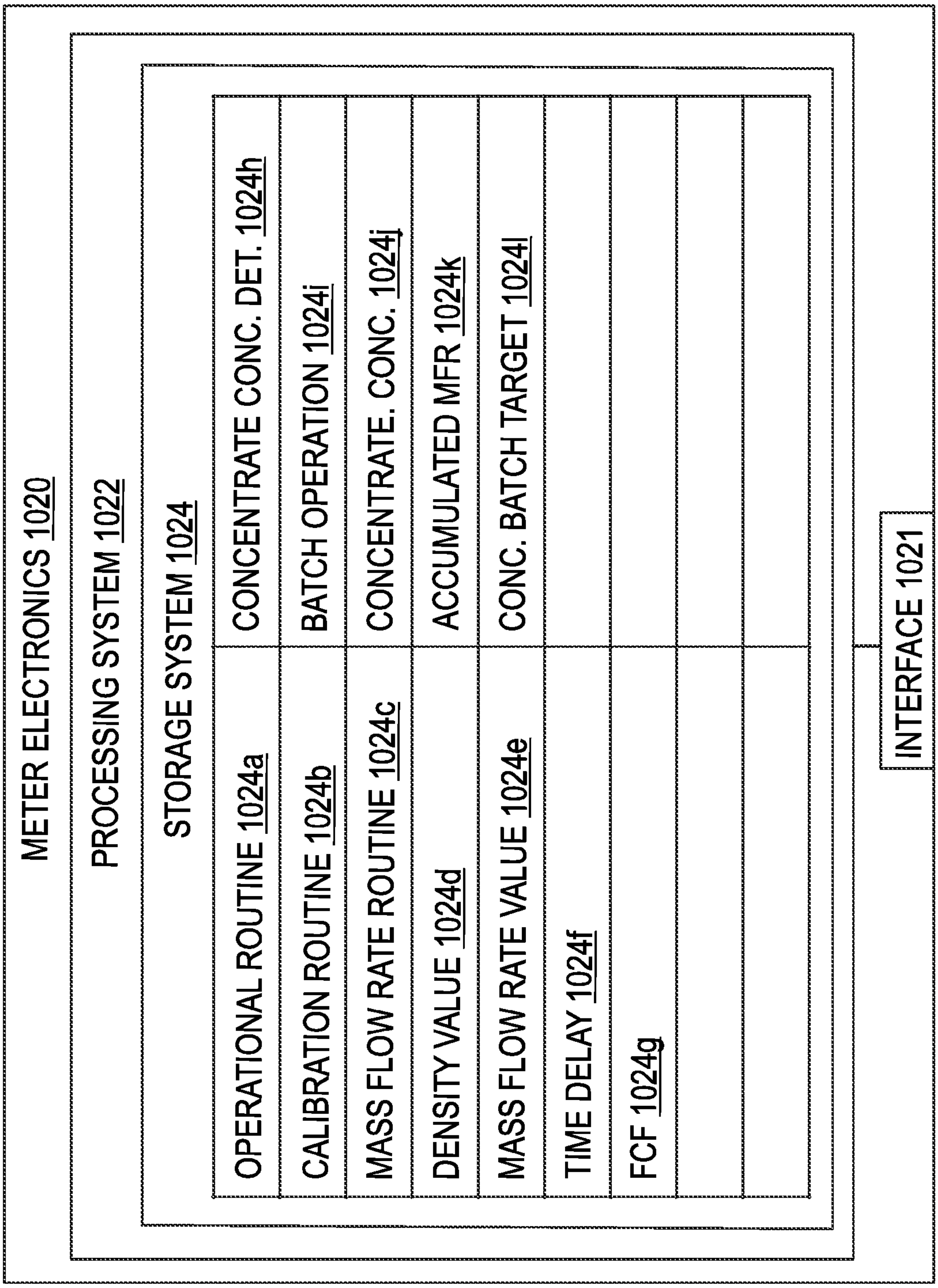

METER ELECTRONICS 1020
PROCESSING SYSTEM 1022
STORAGE SYSTEM 1024
OPERATIONAL ROUTINE 1024a
CALIBRATION ROUTINE 1024b
MASS FLOW RATE ROUTINE 1024c
DENSITY VALUE 1024d
MASS FLOW RATE VALUE 1024e
TIME DELAY 1024f
FCF 1024g
CONCENTRATE CONC. DET. 1024h
BATCH OPERATION 1024i
CONCENTRATE. CONC. 1024j
ACCUMULATED MFR 1024k
CONC. BATCH TARGET 1024l
INTERFACE 1021

FIG. 11

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/085110

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G05D11/13
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 2005/058016 A1 (SMITH MORRIS E [US] ET AL) 17 March 2005 (2005-03-17) paragraphs [0007] - [0028], [0034], [0035]; figures 1-4 | 1-18 |
| A | US 2005/270899 A1 (PHALLEN IVER [US] ET AL) 8 December 2005 (2005-12-08) claims 1-3; figures 1,6 | 1-18 |
| A | US 6 050 282 A (WHALEY ALVIN W [US]) 18 April 2000 (2000-04-18) column 1, line 65 - column 2, line 59; claims 1,2; figure 2 | 1-18 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 18 April 2024 | 14/05/2024 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Camerer, Stephan |

1

# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
PCT/US2023/085110

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| US 2005058016 | A1 | 17-03-2005 | US | 2005058016 | A1 | 17-03-2005 |
| | | | WO | 2005029210 | A1 | 31-03-2005 |
| US 2005270899 | A1 | 08-12-2005 | CA | 2466799 | A1 | 07-11-2005 |
| | | | US | 2005270899 | A1 | 08-12-2005 |
| US 6050282 | A | 18-04-2000 | US | 6050282 | A | 18-04-2000 |
| | | | WO | 9924155 | A2 | 20-05-1999 |