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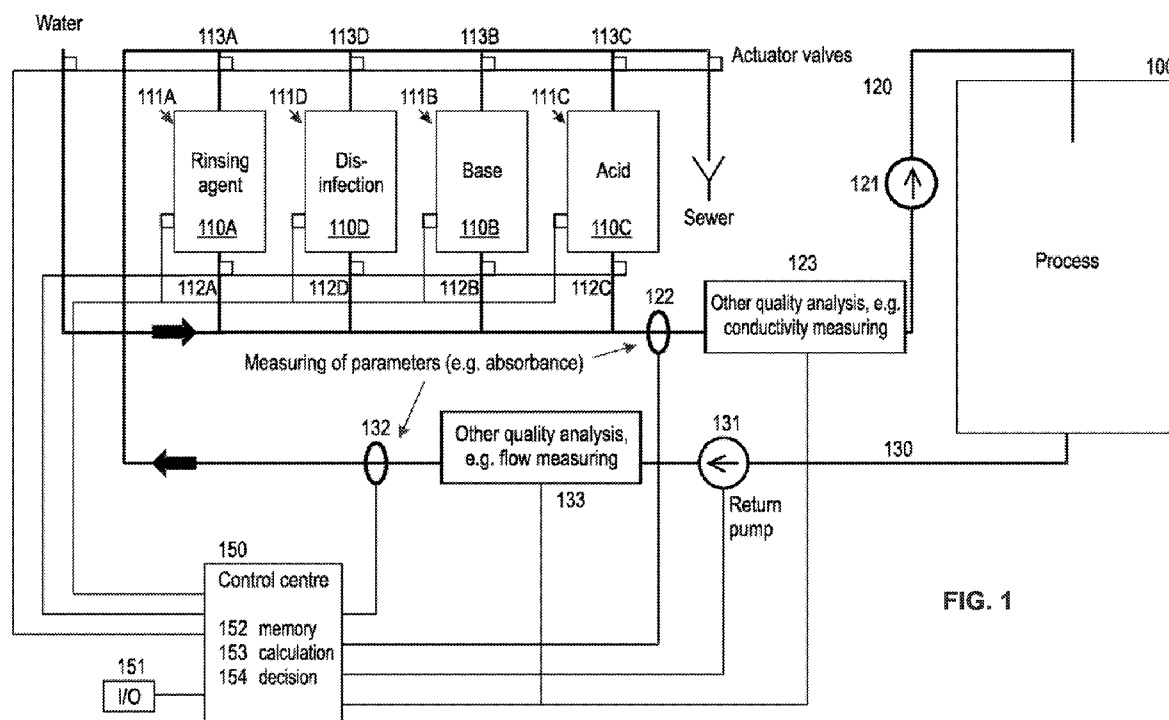


FIG. 1

(57) Abstract: A sensor measurement is filtered by receiving the sensor measurement from a process, measuring a process parameter from the process, evaluating if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element, analyzing whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition; and determining a process condition by filtering any identified sensor noise and any identified process noise. Accuracy and prediction of a process outcome as well as controlling and correction the process will be improved by identifying and correcting for such noise. The sensor measurement may be a sensor from at least one of a supply line of the process and an outlet line of the process where such outlet line may actually be a return line of the process. An automated recirculation system is an example of a process having a return line. The automated recirculation system



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FILTERED AND INTEGRATED SENSOR MEASUREMENT FOR PROCESS CONDITION DETERMINATION AND METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to co-pending U.S. Provisional Application No.
5 62/571,371, filed on October 12, 2017, which is incorporated herein by reference in its
entirety.

FIELD OF INVENTION

The present invention relates to a system and method thereof to filter and integrate a
sensor measurement and/or a process measurement taken from a process plant. The present
10 invention also provides a system and method for predicting and/or determining a process
condition of the process plant using any identified sensor noise and/or process noise.

BACKGROUND

A challenge in any process using instrumentation like a spectrophotometric sensor, for
example, is that the noise from the process or noise from the sensor itself may significantly
15 impact the accuracy and interpretation of the sensor signals. The greater the amount of noise,
the less accurate prediction concern the process operations, which can be made.

For example, an automatic recirculation system such as a clean-in-place (CIP) process
experiences noise from foaming, valve pulsing, water hammering, a dip in signaling, a spike
in signaling, a change in temperature, a change in process flow, chemical reaction, and dosing
20 cleaning chemistry affects. A spectrophotometric sensor used in an automatic recirculation
system may experience noise as a result of quantization, electromagnetic interference,
calibration error, mechanical stability, moisture impact, and correlation error. Within the CIP
process, a failure to properly correct the sensor signal impacts the prediction for when
constant soil concentration is reached as well as a failure to accurately predict the end of the
25 rinse or wash step. If only one sensor is used, for example in the return line of the CIP
process, then the accuracy of soil concentration and the estimate for when the rinse or wash
step should end is even more so impacted.

The sensitivity of sensors is influenced by the ability of the sensor to detect or
perceive a given change in process condition but is also influenced by naturally occurring
30 noise with the manufacturing or process plant. The power of this noise within the sensor or
receiver reception bandwidth is given by the well-known formula:

$$W=KTFBG$$

where “W” is the nominal or average noise power, “K” is Boltzmann’s Constant, “T” is the absolute temperature, “F” is the noise figure, “B” is the reception bandwidth and “G” is the gain.

Conventionally, linear-based techniques have been used to attempt to improve the sensitivity of a sensor measurement. One such technique includes preamplifying the signal using a gain that is sufficiently large to overcome the noise imposed on the signal by the sensor device itself or the noise being experienced within the process.

A high quality preamplifier allows for a reduction in the amount of overall noise that may be imposed by the signal device. This linear method attempts to optimize sensitivity to provide an optimum signal to noise ratio being imposed by the signal device itself.

While single input event sensitivity enhancement attempts that use non-linear signal processing are known in the art, the conventional techniques have been deemed to be relatively ineffective at enhancing sensitivity of the sensor especially when accommodating sensor noise and process noise that is being experienced by the manufacturing or process plant when such an operation also experiences intended changes to its operations. The use of such an ineffectively conditioned sensor measurement further adds complication when attempting to identify a process condition being experienced within the manufacturing or process plant and correctly responding to such a process condition occurrence.

Some sensor noise elimination techniques have been imposed where the extent of noise being filtered from the measured value is variable depending upon the magnitude of the measured value. However, such techniques assume this relationship always remains true and fails to correct for any actual process noise being imposed upon the sensor measurement. Thus, such techniques tend to prove inadequate especially for sensor measurements taken from manufacturing or process plants.

In particular, for automatic recirculation systems such as a CIP process, noise from a spectrophotometric sensor can impact the accuracy and interpretation of the absorbance signal. Such noise makes it difficult to conclude from the slope of the measurement curve when the wash solution being analyzed by the sensor reaches constant soil concentration that otherwise allows for when the end of the rinse or wash is in the process. Furthermore, if only one spectrophotometric sensor in a return line is used, then there typically is insufficient information to make an accurate analysis. EP2363008B1, fully incorporated herein by reference, identifies a preferred arrangement when there are two sets of probes—one in the supply line and the other in the return line—but still may impose varying variations in their separate analyses that requires correction.

There remains a need in the art to provide a sensor filtration technique that accommodates sensor noise, process noise and analysis method noise. There remains a particular need in the art to filter and integrate spectrophotometric sensor and other CIP process parameters such as, but not limited to flow rate, temperature and conductivity.

SUMMARY OF INVENTION

The present invention relates to a system and method to filter and integrate a sensor measurement and/or a process measurement taken from a process plant. Without intending to be bound by theory, a system and method of the invention allows a process condition of the process plant using any identified sensor noise and/or process noise to be more accurately determined.

An aspect of the invention provides a method for filtering a sensor measurement including the steps of receiving the sensor measurement from a process; measuring a process parameter from the process; evaluating if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element; analyzing whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition; and predicting and/or determining a process condition by filtering any identified sensor noise and any identified process noise.

In certain embodiments of the invention, the sensor measurement is a sensor from at least one of a supply line of the process and an outlet line of the process. Further pursuant to this embodiment of the invention, the outlet line is a return line of the process.

In an embodiment of the invention, the process condition may include predicting the process condition. In another embodiment of the invention, the process may be controlled by using the sensor measurement that has been filtered.

In certain embodiments of the invention, determining the process condition comprises correcting the sensor measurement and the process parameter for any process noise that is identified. In certain embodiments of the invention, the sensor noise element is caused by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical instability, a moisture influence, and a correlation error.

In an embodiment of the invention, the process may be an automated recirculation system. An automated recirculation system of the invention may comprise any one of a clean-in-place (CIP) process, a bottle wash process, a crate wash process, a tunnel pasteurizer, a heating loop, a cooling loop, an evaporator, a membrane treatment process, an

exterior filler cleaning system, a shrink tunnel, a fryer, a mechanical ware washing process. The sensor noise element may be caused by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical instability, a moisture influence, and a correlation error, according to certain embodiments of the invention.

5 In an embodiment of the invention, the automated recirculation system may comprise a CIP process. Further pursuant to this embodiment of the invention, the process noise element is caused by any one or more of a foaming, a valve pulsing, a water hammering, a dip in signaling, a spike in signaling, a change in temperature, a change in process flow, a chemical reaction, and a dosing cleaning chemistry affect. Still further pursuant to this
10 embodiment of the invention, the process parameter comprises any one or more of a temperature, a pressure, a conductivity, a flow rate, a pH, a time, a total flow volume, a wash sequence step, an object being cleaned, a spectrophotometer, total organic carbon (TOC), adenosine triphosphate (ATP), redox potential (ORP), chemical oxygen demand (COD), biological oxygen demand (BOD), a detergent component concentration, a disinfectant
15 component concentration, a sanitizer component concentration, a pump signal, a valve signal, and a level.

In an embodiment of the invention, the step for correcting the sensor measurement may comprise filtering an absorbance data from a sensor used to provide the analyzer measurement. In certain embodiments of the invention, the analyzer measurement may
20 include an analysis method noise element that itself may require determination and possible correction. Further pursuant to this embodiment of the invention, the absorbance data includes absorbance of electromagnetic radiation or a quantity derived therefrom at least at one wavelength, the wavelength being within a range of about 100 to about 3000 nm, or alternatively, the wavelength being within a range of about 230 to about 1100 nm. Still
25 further pursuant to this embodiment of the invention, the absorbance data includes absorbance of electromagnetic radiation or a quantity derived therefrom at a plurality of discrete wavelengths within a range of about 100 to about 3000 nm, or, alternatively, the plurality of discrete wavelengths is within a range of about 230 to about 1100 nm. Still even further pursuant to this embodiment of the invention, the absorbance data includes a total
30 absorbance of electromagnetic radiation or a quantity derived therefrom at least in one wavelength range having an upper limit and a lower limit within a range of about 100 and about 3000 nm, or, alternatively, the at least in one wavelength range having an upper limit and a lower limit within a range of about 230 and about 1100 nm.

Further pursuant to this embodiment of the invention, correcting the sensor measurement may additionally include integrating the absorbance data from the sensor with data from the process parameter.

Further pursuant to the embodiment of the invention, whereby the process is an automated recirculation system, the method for filtering the sensor measurement additionally comprises the step of predicting and/or determining if a process step has completed based upon the filtered sensor measurement. Further pursuant to this embodiment of the invention, the automated recirculation system may be a CIP process, and the method for filtering the sensor measurement may additionally comprise determining an extent of cleaning of the process. In certain embodiments of the invention, the extent of cleaning of the process comprises an extent of rinsing of the process.

In an embodiment of the invention, at least one of the sensor measurement and the process parameter is corrected according to at least one of in real time and statically.

In an embodiment of the invention, the method for filtering the sensor measurement may additionally comprise receiving another sensor measurement from the process; measuring another process parameter from the process; additionally evaluating if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise element; additionally analyzing whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an additional process noise and the change in process condition; and determining the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise. Further pursuant to this embodiment of the invention, the sensor measurement and the process measurement are from a supply line of the process and the additional sensor measurement and the additional process measurement are from an outlet line of the process. In certain embodiments of the invention, the process is an automated recirculation process and the outlet line is a return line of the process.

In an embodiment of the invention, an algorithm may be used in determining whether at least one of the sensor noise element and the process noise element affects the sensor measurement in the method of filtering the sensor measurement. Further pursuant to this embodiment of the invention, the algorithm is used in determining whether at least one of the sensor noise element and the process noise element is affected by at least one of the sensor noise, the process noise and the change in process condition.

According to certain embodiments of the invention, the sensor noise element and the process noise element comprise a low value and a high value that are used in analyzing whether any identified sensor noise element and process noise element is the result of at least one of the sensor noise, the process noise and the change in process condition. In certain

5 embodiments of the invention, a subsequent filtering process, depending on the extent of the noise element, may result in either no impact or an impact that will affect the sensor and/or the process?

10 In an embodiment of the invention, the method for filtering the sensor measurement may additionally comprise obtaining an analyzer measurement using an analysis method; and evaluating if the analyzer measurement possesses an analysis method noise element, wherein analyzing whether any identified analysis method noise element is the result of an analysis method noise and determining the process condition additionally comprises filtering any identified analysis method noise.

15 Further pursuant to this embodiment of the invention, the method for filtering the sensor measurement may additionally comprise controlling the process using the sensor measurement that has been filtered. In certain embodiments of the invention, determining the process condition comprises correcting the sensor measurement, the process parameter and the analysis method for any process noise that is identified.

20 In another aspect of the invention, the invention provides a measurement equipment to filter a sensor measurement, the measurement equipment comprising an interface for receiving a sensor measurement and a process measurement from a process, and a processor in communication with a memory, wherein the processor is configured to evaluate if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element; analyze whether any identified sensor noise element and

25 process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition; and determine a process condition by filtering any identified sensor noise and any identified process noise. In certain embodiments of the invention, the processor is additionally configured to control the process using the sensor measurement that has been filtered.

30 In an embodiment of the invention, the interface may additionally receive another sensor measurement from the process and another process parameter from the process. Further pursuant to this embodiment of the invention, the processor is additionally configured to evaluate if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise

element, analyze whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an additional process noise and the change in process condition, and determine the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise.

In certain embodiments of the invention, the sensor measurement and the process measurement are from a supply line of the process and the additional sensor measurement and the additional process measurement are from an outlet line of the process. In this embodiment of the invention, the process may be an automated recirculation system.

In certain embodiments of the invention, the processor uses an algorithm to determine whether at least one of the sensor noise element and the process noise element affects the sensor measurement, and may subsequently affect the operation of the process based upon the corrections to the sensor measurement and/or the process measurement.

According to yet another aspect of the invention, a system to filter a sensor measurement is provided comprising an interface that receives a sensor measurement and a process measurement from a process, and a processor in communication with a memory, wherein the processor evaluates if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element; analyzes whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition; and determines a process condition by filtering any identified sensor noise and any identified process noise. Further pursuant to this aspect of the invention, improved accuracy and improved prediction of the process status results.

Other aspects and embodiments will become apparent upon review of the following description. The invention, though, is pointed out with particularity by the included claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1 is a diagram illustrating, by way of example, an arrangement for implementing a multistep washing process;

FIG. 2 is a schematic view of a sensor measuring absorbance;

FIG. 3 is a diagram showing absorbance measured in a return channel as a function of time during one washing step;

FIG. 4 shows measured absorbance as a function of time in an exemplary washing process;

FIG. 5 is a flowchart showing a sequence of steps to filter and integrate sensor measurements and process condition determination;

5 FIG. 6 is a block diagram showing the steps that may be involved in a process classification and efficiency time analysis according to an embodiment of the invention; and

FIG. 7 is a block diagram showing the steps that may be involved in an automated analysis according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

10 The present invention now will be described more fully hereinafter. Preferred embodiments of the invention may be described, but this invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in
15 the art. The embodiments of the invention are not to be interpreted in any way as limiting the invention.

As used in the specification and in the appended claims, the singular forms “a”, “an”, and “the” include plural referents unless the context clearly indicates otherwise. For example, reference to “a sensor measurement” includes a plurality of such sensor
20 measurements.

Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation. All terms, including technical and scientific terms, as used herein, have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs unless a term has been otherwise
25 defined. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning as commonly understood by a person having ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and
30 the present disclosure. Such commonly used terms will not be interpreted in an idealized or overly formal sense unless the disclosure herein expressly so defines otherwise.

As used herein, a "signal" refers to a time-varying analog and/or digital representation for some other time varying quantity taken from a manufacturing or process plant. For

example, a signal corresponds to a time varying representation of the quantity for a sensor measurement of the manufacturing or process plant. Such sensor measurements may, for example, correspond to values representing the chemical makeup of a manufacturing or process plant stream.

5 While the exemplary process further described herein is a multistep washing process, the invention may be applied to any type of manufacturing or process plant.

FIG. 1 is a diagram illustrating an exemplary representation of a multistep washing process. A washing process **100** is utilizing various chemical solutions, namely, a rinsing agent **110A**, a base solution **110B**, an acid solution **110C**, and a disinfectant solution **110D** are shown in this exemplary representation. An important objective in the control of the washing process **100** is an optimal action time with the use of these solutions. The rinsing agent **110A**, the base solution **110B**, the acid solution **110C**, and the disinfectant solution **110D** may be introduced to the washing process **100** through a feed channel **120** using, in a non-limiting example, a feed pump **121**. These chemical solutions may be introduced through the use of any known technique, such as through pumping, the use of pressurized gas and/or gravity conveyance. Remote-controlled valves **112A**, **112B**, **112C** and **112D**, each respectively corresponding to the containers for the rinsing agent **110A**, the base solution **110B**, the acid solution **110C**, and the disinfectant solution **110D** may, can be opened to allow the respective chemical solution to be directed to the feed channel **120** using, in a non-limiting example, a feed pump **121**. The respective chemical solution fed through the washing process **100** may be returned to the respective container holding such chemical solution, i.e., a rinsing solution container **111A**, a disinfectant solution container **111B**, a base solution container **111C**, and an acid solution container **111D**, through a return channel **130**. Such solution is allowed to be fed back to its respective container when a second remote-controlled valve **113A**, **113B**, **113C** and **113D** corresponding to the respective container is opened. A return pump **131** facilitates the return of the respective chemical solution from the washing process **100** via the return channel **130** to the respective container **111A**, **111B**, **111C** and **111D**. However, other return arrangements well-known in the art may be used instead.

30 In the exemplary embodiment of FIG. 1, a feed channel sensor **122** and a return channel sensor **132** measures at least one parameter that indicates directly or indirectly the purity of the respective chemical in the corresponding feed channel **120** and return channel **130**. The purity of the chemical may be directly measured, but may also be indicated indirectly. In a non-limiting example, a quantity representing the purity or, more precisely,

the impurity of the chemical may be a concentration of foreign substances. Sometimes it is difficult, or at least slow and complicated, to measure directly a concentration in a real-time process, and consequently it is advantageous to indicate the concentration indirectly through absorbance. In the event it were desirable to find out the concentration of impurities in the chemical as an absolute quantity, it would be possible to find out experimentally the dependence between the absorbance and the concentration of impurities. Dependence between direct and indirect indications of impurity would be different for different impurities and chemicals, however. This information may be utilized in deciding which wavelengths or wavelength ranges the feed channel sensor **122**, and the return channel sensor **132** would monitor. In an exemplary non-limiting example, a wavelength range of 660 to 880 nm would measure milk as an impurity when the washing process **100** processes milk.

Other types of quality analyzers may be used, for example, using a feed channel parameter **123** and/or a return channel parameter **133**. Generally, these types of parameters may assess or analyze the quality of a chemical without making a comparison between the feed channel **120** and the return channel **130**. By way of example, without intending to be limiting, the feed channel parameter **123** and/or the return channel parameter **133** may be any one or more of a conductivity analyzer, a flow measurement sensor, a pH analyzer, a temperature thermocouple, a resistance temperature detector (RTD), and a soil analyzer.

A control center **150** may receive parameter data indicating the impurity of the chemical in the feed channel **120** and the return channel **130** from the respective feed channel sensor **122** and return channel sensor **132**. Additionally, the control center **150** may receive other measurement data to be used in the quality analysis from the feed channel parameter **123** and the return channel parameter **133**. Indeed, the control center **150** may receive any information available from the washing process **100** to assess and provide a user information on the state of the washing process **100**. The control center **150** accords such interaction with the user via input/output (I/O) **151**. The control center **150** may have memory **152** for storage of information, code, etc.; perform a calculation **153** or indeed multiple calculations; and make a decision **154** concerning the waste process **100** and advising the user of the results of such information via I/O **151**.

FIG. 2 is a schematic view of a sensor **200** that measures absorbance. Absorbance is a good, but non-restrictive, example of a parameter indicating impurity of a chemical, whereby the sensor **200** is a non-restrictive example of the feed channel sensor **122** and the return channel sensor **132** for respectively analyzing the feed channel **120** and the return channel **130** of FIG. 1. The sensor **200** includes a connection **202** that allows the output of the sensor

200 to be sent to the control center **150**. The sensor **200** comprises a source **204** and a receiver **206** for transmitting electromagnetic radiation **208** across the chemical passing in the respective channel **120**, **130**. The electromagnetic radiation is referred to herein as "light" without intending to be limiting, since it is advantageous to measure absorbance, instead of or
5 in addition to visible light, using an infrared wavelength and/or an ultraviolet wavelength range.

In order to indicate a plurality of different impurities it is advantageous that the sensor **200** or sensor set is arranged to measure absorbance at several distinct wavelengths or wavelength ranges. This may be implemented by using a plurality of sensors in connection
10 with the respective channel **120**, **130**, configured to measure absorbance at different wavelengths. Alternatively, it is possible to place in one sensor a broad-spectrum light source **204** or a plurality of light sources for different narrower wavelength ranges, and a plurality of separate light receivers **206**, each of which are sensitive to a particular narrow wavelength range. According to yet another arrangement, the sensor **200** may comprise one receiver **206**
15 covering a wide wavelength range and a plurality of light sources **204** for different, narrower wavelength ranges, and of the plurality of light sources **204** there is activated, in each washing process step, the light source or the light sources whereby the absorbance of wavelengths produced best indicates the impurities that are to be removed in each particular step of the washing process.

In a non-restrictive example, the light source **204** may comprise one or more semiconductor lights (LED), an incandescent lamp, a gas-discharge lamp, a laser or any combination thereof. The light receiver may comprise one or more semiconductor sensors, whose active element may be made, for instance, of silica, cadmium sulfide or selenium. Alternatively, or in addition thereto, a photomultiplier tube, a charge-coupled device, may
25 serve as the light receiver. Between the light source **204** and the light receiver **206** there may be one or more optical filters, which allow to pass the wavelengths that best indicate the expected impurities. According to an embodiment, the filter may be electrically controllable by an external control signal, and consequently the control center **150** may change the wavelength or wavelengths at which the monitoring takes place by adjusting or changing the
30 filter. An electrically controllable filter of this kind may be implemented, for instance, by a technique that is known from video projectors. Alternatively, the sensor **200** may include, for instance, a plate rotating about an axis and having a plurality of different filters for different wavelengths.

In certain embodiments of the invention, the receiver may comprise either a wide or a narrow spectrum imaging sensor (e.g., CCD, CMOS, etc.) with or without lens that would in addition to light intensity measure also the shape of the received beam or with lens and focusing to obtain actual images of the process fluid. In certain embodiments of the invention, lenses and reflective and semi-reflective mirrors may be used to shape, split and reflect the light beam through one or many optical paths through the process fluid to one or any number of receivers.

FIG. 3 is a diagram showing a quality parameter measured in the return channel **130**, for instance a descending function of absorbance, such as an inverse value, as a function of time during one washing step. Because, the action time of a chemical is determined on the basis of the mutual uniformity of the first and the second monitored parameter sets, it is irrelevant how the parameter representing the quality of the chemical is deduced from the absorbance (or another parameter indicating impurity). In the diagram of FIG. 3, the x-axis represents time t and the y-axis represents a quality parameter of the chemical, such as an inverse value of absorbance. A broken line **302** indicates the quality parameter of the chemical in the feed channel **120** of which the measured value quality parameter of the chemical that is in the return channel **304**, cannot exceed this. When a washing step is started at a time instant $t = 0$, it will take some time until the amount of impurities, for example soil, in the return channel reaches its maximum, for example with soil saturation (the quality parameter **304** reaches its minimum). Thereafter, when any of the chemical solutions **110A**, **110B**, **110C** and **110D** are directed to the washing process **100**, soiled chemical is returned via the return channel **130** to the respective container of said chemical **111A**, **111B**, **111C** and **111D**, wherefrom purer chemical will be conveyed to the washing process **100**.

Even though the quality parameter **302** of the chemical in the feed channel **120** seems constant in relation to time, it actually descends gradually with time, when impurities migrate from the washing process into the respective chemical container. Therefore, it is advantageous to monitor the output signal of the feed channel sensor **122**, i.e. the parameter indicating quality, as an absolute value and not only the uniformity of the sensors **122**, **132**. When the output signal **302** of the feed channel sensor **122** goes below a predetermined limit, that chemical solution of the batch may be deemed used up.

A particular time instant **306** shows when the control center **150** observes that the output signals of the feed channel sensor **122** and the return channel sensor **132** become substantially uniform within the predetermined limits, and in that case the control center **150** may infer that the chemical then in use no longer has any cleaning effect, whereby under the control of the control center **150** the washing process may be directed to proceed to a next

step. In the event this uniformity was not measured, the control center **150** would have to wait until the worst-case time **308** as determined by, for example, past experience before proceeding to a next washing step. The time between the worst-case time **308** and the time instant **306** represents a time savings. The particular times represented by the graph of FIG. 3 will vary depending upon the extent of noise in the sensor and the process parameter(s).

FIG. 4 shows a measured quality parameter, for instance, an inverse value of absorbance, as a function of time in an exemplary washing process. The exemplary washing process of FIG. 4 involves the washing of dairy reception pipelines. Curve **402** describes the purity of a chemical in the feed channel **120** and curve **404** in the return channel **130**, respectively. In the case of Figure 4, washing starts by pumping a pre-rinsing agent approximately at time instant $t = 3$ min. Chemicals to be used after the pre-rinsing agent are a base ($t = 10$ min), an intermediate rinsing agent ($t = 20$ min), an acid ($t = 27$ min) and a final rinsing agent ($t = 35$ min). Reference numerals **406a** to **406e** indicate time instants, when the parameters indicating purity of the chemical, monitored in the feed channel **120** and the return channel **130**, are uniform within a predetermined margin. Time delays 2 min, 4 min, etc., which follow reference numerals **406a** to **406e**, represent times when the chemical in the washing process instance of FIG. 4 no longer has any cleaning effect.

In case when the measuring is employed in real-time washing process control, these time delays may be eliminated by proceeding to a subsequent washing process step at time instants **406a** to **406e**. Whereas, if the measuring is employed in non-real-time washing process control, measuring equipment connected to, or separate from, the control center **150** may store in the memory time instants **406a** to **406e**, originating from a plurality of washing process instances, in relation to time when said washing step was started. The obtained times are durations in said washing process instances, during which the chemicals have a cleaning effect (within a predetermined margin). By repeating the measuring of FIG. 4 over a sufficient number of washing process instances, it is possible to determine a data set, which directly or indirectly indicates, with reasonable reliability, the worst-case durations for each washing process step.

One major challenge in the use of a sensor and other parameter information received from a manufacturing or a process plant, such as the exemplary washing process described herein is that noise from the manufacturing or process plant may impact the accuracy and a proper interpretation of the state of the process based upon such measured data. The greater the amount of noise, the less accurate prediction concerning the status of the process that can be made.

For example, with respect to a clean in place (CIP) process, a spectrophotometric sensor used in the measurement of certain properties may be affected by noise related to foaming, valve pulsing, water hammer and unexplained changes in signal, process parameters such as temperature and flow rate, for example, chemical reaction, dosing cleaning chemistry or even the sensor itself (e.g., quantization, electromagnetic interference, calibration error, mechanical instability, impact of moisture, and correlation error.

The inventors have conceived of a technique to filter and integrate any signal information, such as absorbance data (e.g., a spectrophotometric sensor) from a washing process, for example, with additional process parameter measurements such as a conductivity analyzer, a flow measurement sensor, a pH analyzer, a temperature thermocouple, a resistance temperature detector (RTD), and a soil analyzer according to certain non-limiting examples to improve any process prediction made using such measured information.

FIG. 5 is a flowchart showing a sequence of steps to filter and integrate sensor measurements and process condition determination. The process to filter sensor measurements and determine process condition **500** includes the collection of one, but preferably more than one, physical measurements **510** that are specifically targeted for process monitoring and correction are collected from the process. Such physical measurements can include, but are not limited to, a temperature, a concentration, a flow rate, and a soil level (the latter, in particular, being preferred when the process is a washing process, such as the exemplary process shown in FIG. 1). Such physical measurements may also include at least one sensor measurement. Process noise **520** and sensor noise **530** from the one or more sensors is determined from the physical measurements, preferably, a collection of such physical measurements taken over time. The physical measurements **510**, any process noise **520** and any sensor noise **530** are subjected to a correlation procedure **540**, of which some correlation methods are further discussed herein. The correlation procedure **540** at least in part determines the extent of correction of the physical measurements **510** to correct for process noise **520** and sensor noise **530** that may be encompassed in the raw data collected from the process to provide correlated data **545**. The correlated data from the correlation procedure **540** is subjected to a filter **550** to provide filtered noise **554** and filtered sensor and parameter data **555**. The filtered noise **554** is analyzed and processed, as further described herein, to distinguish between a hygiene impact **560**, which is a change in process condition, and noise experienced by the process and/or sensor (i.e., any process noise and any sensor noise) that results in an analysis impact **570**. The hygiene impact **560** and analysis impact **570** may respectively result in the calculation of a hygiene impact key performance

indicator (KPI) and an analysis impact KPI, respectively, to provide a quantifiable measure to evaluate the extent of the impact of hygiene and the impact on analysis that is occurring. The information from the hygiene impact **560** and the analysis impact **570** is evaluated to provide a reliability KPI **580**.

5 The filtered sensor and parameter data **555** is used by a process calculation procedure **590** to accomplish some important process object, in particular, providing process information and/or direction **600**. Since the filtered sensor and parameter data **555** has been subjected to correlation procedure **540** to compensate for any process noise **520** and any sensor noise **530** that has been identified, the filtered sensor and parameter data **555** will more
10 correctly reflect the actual operation of the process. For example, in certain embodiments of the invention, the process calculation procedure **590** is a control algorithm and the process information and/or direction **600** is a recommended control action to maintain a desired target for a sensor variable provided by the filtered sensor and parameter data **555**.

 In another embodiment of the invention, the process calculation procedure **590** is a
15 process recipe calculation procedure. Such a process recipe calculation procedure can be used in, for example, without intending to be limiting, a clean-in-place process, a wash-in-place process, and a sterilization-in-place process. In the case of these types of processes, the process recipe calculation procedure considers the product being processed and being cleaned from the process, the object of the process, the actual process itself, and the chemistry of the
20 current step in the process. For example, such a process recipe calculation procedure for a clean in place process may comprise a cleaning step, a wash step, a disinfection step, a sanitization step, and a rinse step. The filtered sensor and parameter data **555** provides the process calculation procedure **590** with a more accurate insight into the state of the process. In these types of exemplary processes, the process calculation procedure **590** that is a recipe
25 calculation procedure may provide, for example, process information and/or direction **600** concerning the effective time of the process and perhaps an estimate of remaining time to complete the recipe.

 A person having ordinary skill in the art can envision many other types of process calculation procedures **590** and process information and/or direction **600** may be
30 implemented using the filtered sensor and parameter data **555** having the benefit of this disclosure.

 FIG. 6 is a block diagram showing the steps that may be involved in a process classification and efficiency time analysis according to an embodiment of the invention. FIG. 6 is application of the invention to a CIP process. This exemplary representation of the

invention includes five categories of steps. As shown in FIG. 6, these categories are Process Parameters, Skilled Specialist, Process Information, Automation and Algorithm. Beginning with the Process Parameters section, the absorption temperature conductivity wash log **610** is collected and directed to the automatic wash phase classification **620** step in the Automation category. The automatic wash phase algorithm refinement **630** step in Algorithm Refinement may choose to make changes to the automatic wash phase classification **620**. The automatic wash phase classification **620** step directs needed input to the wash list with phases **640** step to better direct the activities in this Process Information category. Based upon Skilled Specialist information, a comparison of actual run data recipes from pre-study **650** uses the information from the wash list with phases **640** activity to perform the needed comparison function.

The sanitation standard operating procedure (SSOP) parameters **660** and the automatic wash phase classification **620** information is directed to the phase analysis/analysis case classifications and effective timers **670**, which is an Automation function. Again, data from the phase analysis/analysis case classifications and effective timers **670**, step may be subjected to algorithm refinement **680**. The information from the phase analysis/analysis case classifications and effective timers **670** step is directed to the classified wash automatically generated recommendations **690** step in the Process Information category. The classified wash automatically generated recommendations **690** is used in the key performance indicators (KPIs) **700** of the Process Information category and additionally used in the Skilled Specialist procedure phases requiring manual check for outliers **710**. Information from the phases requiring manual check for outliers **710** step is directed to both recommendations and case solutions **720**, a Skilled Specialist category step, and the recommendations for manual changes **730**, a Process Information category step. The information from the recommendations and case solutions **720** may be used in the Process Parameter category step changes to process **740**.

FIG. 7 is a block diagram showing the steps that may be involved in an automated analysis according to an embodiment of the invention. This exemplary representation of the invention includes three categories of steps. As shown in FIG. 7, these categories are Input/Output, Automation Layer and Manual Refinement. The wash phases and measurement signals **750** of the Input/Output category, the best guess algorithms **760** and refined algorithms **780** both of the Manual Refinement category are brought together for an analysis in the first efficient times and noise signals **770** of the Automation Layer. This is directed to the next step of efficient time and noise signals at those times **790** analysis, which,

together with more advanced features of analysis **800**, are sent the low hanging fruits giraffe class **810** to be identified. From here, washes having “good” classification and reliable efficient times **820** are identified, which are directed to distribution analysis and manual outliers **830** that provides input to the refined algorithms **780** step.

Information from the washes having “good” classification and reliable efficient times **820** step is also directed to the outliers, washes having “bad” classifications and washes that need manual verification **840**, which also obtains information from the distribution analysis and manual outliers **830** step. Furthermore, information from the washes having “good” classification and reliable efficient times **820** step is additionally directed to the manual validation, first/easy actions based on classifications **850** identification step. Information from both the washes having “bad” classifications and washes that need manual verification **840** step and the manual validation, first/easy actions based on classifications **850** step is used by the statistically representative set of efficient time that distributes with enough normality to use six sigma **860**, which further leads to recommendations, savings estimates on low hanging fruits and potential further savings (cost/benefit) **870**.

In certain configurations, depending on the process, a sensor unit consists of a short length of main pipe, a side stream pipe, flow, conductivity and temperature sensors and a spectrophotometer. The spectrophotometer is typically located in the side stream pipe and the conductivity, flow and temperature sensors are typically in the main pipe. The side stream pipe may be isolated from the main pipe with two valves in the ends. For spectrophotometric sensors, the optical measurement cell occupies a volume inside the spectrophotometer measurement head and in the near surroundings. The spectrophotometer measures the amount of light that traverses this volume in different wavelengths. In this scenario, noise is something that causes the measured signal to deviate from the actual physical quantity.

Without intending to be limiting, sensor measurement noise may include quantization noise, electromagnetic interference (EMI), calibration error, mechanical stability and moisture impact.

In particular, for an automatic recirculation system, the absorbance data from any sensor (e.g., a spectrophotometric sensor) is filtered and integrated along with data from other cleaning process parameters to improve the accuracy of prediction of the end of cycle measured by such a sensor also allowing the absorbance data to be normalized. Such cycle ends may comprise, for example, a cleaning step, a wash step, a disinfection step, a sanitation step, and/or a rinse step. Judgment concerning the reliability of the end outcome is also improved.

Process induced noise causes a measurement device to measure something other than the intended physical quantity. When the desired quantity is derived from another quantity that is in relation to the first, noise causes that relationship to change. Non-limiting examples of process elements that may result in process noise include foam, valves, trends over time, small bumps and dips in a signal, non-optimum functionality and/or assembly, loading of a wash chemical or some other additive, temperature or any process changes, chemical reactions, changes in flow rates, and concentration changes.

Some solutions foam when they are washed with a caustic solution, for example, such as in tanks or silos. Foam may cause the liquid to become very absorbent primarily as a result of air bubbles scattering the light all around. It becomes more difficult to accurately measure the properties of the liquid through absorption when there is foam in a measurement cell. Valves may be used to help circumvent the foam problem. Valves are used to stop the flow in the optical measurement cell. The unit is designed so that when the flow stops, air rises upwards and the measurement cell becomes free of any bubbles that have formed. The time it takes to deaerate the solution is process dependent. Slower, periodic sampling instead of real time measurement cause measurement accuracy to become reduced. Slower sampling has a more profound impact to temporal accuracy because instead of one sample per second one sample on longer intervals is received. This also results in delay because, while the measured sample may have been valid at the time when the valves closed but not when the foam has disappeared. To reduce the valve sampling noise, sophisticated interpolation is used. The delay is also easily removed with temporal shift.

Constant trending in noise may occur over time. This kind of noise may sometimes be found in circulating washing liquids. For example, absorption can be used to measure the amount of soil/product in the solution. The problem is that as the hot chemical mixes with the product, sometimes changes may occur in the optical properties of the product causing the washing liquid to seem to have become more soiled (downwards trend) or cleaner over time (upwards trend) even though the amount of product remains the same.

Sometime bumps or dips may occur in signals. For example, when the product does not dissolve easily into the washing liquid or when it does not become removed more steadily, but rather in lumps, the uneven soiling of the washing liquid can be seen as bumps and dips in the signal. These must be carefully analyzed to ensure it becomes apparent when dirt is circulating through the sensor.

An assembly that has not been optimized may create noise problems. Measurement pipes should be full of liquid to make accurate measurement. Less than optimal assembly

may cause the pipes to not be full of liquid. This results in bad measurements from all of the measured signals. If the optical measurement cell is not in the bottom of the unit, air may get too close to the cell or the cell may be drained partially or completely. Liquid surface too near the cell causes reflections that disturb the measurement. Good assembly instructions and professional assembly teams reduce the risk of bad assembly. Little can be done afterwards if the assembly is not correct.

If the flow through the sensor unit and especially through the side stream is very low, the washing effect may not be sufficient to keep the optical measurement cell free of biofilm and other kinds of dirt. Also, if foam removal requires long stops in flow through the side stream, the washing effect may be reduced. Good assembly ensures sufficient flow. Also, keeping the valves open periodically ensures that the side stream remains clean.

Most electromagnetic noise induced by the environment and the sensor devices causes an interpretation that the signal has white noise. As the changes in the process that are measured have low frequency ($<1\text{Hz}$) most of the white noise is already filtered before the digital conversion. After that the signal can be filtered even more depending on what is of interest. The peak-to-peak voltage of a digitally filtered noise is monitored to give an indication of the sensor's health and also for measuring the SNR that is used for calculating the reliability of the analysis results.

Chemical reactions affecting process noise may be corrected by collecting data from laboratory and process environment tests to better understand how products and chemicals react. This information may be used to compensate for any trends caused by such reactions.

While the sensors are calibrated to show the same value, small deviations typically exist between sensors. In the case of spectrophotometers and conductance meters, errors may be estimated when the same liquid flows through the sensors. Parameters other than just the difference between two sensors may be taken into account when analyzing the efficient time. For example, derivatives of the forward and return signal and derivative of the difference signal may be used. This approach allows the effect of small mismatch in sensors to become reduced.

Parameter or process data from a CIP process may include, without limitation, a temperature, a pressure, a conductivity, a flow rate, a pH, a time, a total flow volume, a wash sequence step, an object being cleaned, a spectrophotometer, total organic carbon (TOC), adenosine triphosphate (ATP), redox potential (ORP), chemical oxygen demand (COD), biological oxygen demand (BOD), a detergent component concentration, a sanitizer component concentration, a pump signal, a valve signal, and a level. An automatic

recirculation system includes, but is not limited to, a clean-in-place (CIP) process, a bottle wash process, a crate wash process, a tunnel pasteurizer, a heating loop, a cooling loop, an evaporator, a membrane treatment process, an exterior filler cleaning system, a shrink tunnel, a fryer, a mechanical ware washing process. In such an automated recirculation system, sensor and process parameters are measured at least in the return line. However, typically, in such automated recirculation systems, sensor and process parameters are measured in both the supply and return line, and may even be from multiple points within those lines.

In an embodiment of the invention, a noise element—which include sensor noise, process noise, analysis method noise, and any combination thereof—may be evaluated by an algorithm, as further described herein, to determine whether the noise element is impacting any of the measurements in some way. If the algorithm detects a noise element, such noise element will be characterized as having an impact to analysis that is the result of a sensor noise, a process noise, an analysis method noise, and any combination thereof. Alternatively, the detected change may be identified as an actual change in a process condition that itself affects the measurement value otherwise known as an impact to hygiene.

All noise types are assigned a value ranging from a low value to a high value depending upon the impact to analysis and the impact to hygiene. The extent of magnitude of the noise will be estimated, and any identified impact to analysis corrected to allow for a more accurate analysis of the process. Thus, each noise type will be comprised of an impact value and a magnitude value.

A sum of the impact value and the magnitude value will result in a reliability key performance indicator (KPI) for each of the measurements. The less noise present in any of the measurements, results in a reliability KPI that demonstrates the associated measurement as being more reliable relative to the outcome of the analysis. The array of sensor values must be accurate in order to understand the variations of chemical concentrations changes, temperature change, and the like. Appropriately correcting any errors in these values allows for more precise predictions concerning the process. For example, in CIP processes, changes in soil level may more accurately be determined using corrected sensor measurements allowing for more precise predictions with respect to the end of clean or end of a wash cycle.

In an embodiment of the invention, the data analysis may result in adjustments to process parameters that are in real time. In another embodiment of the invention, the data analysis may result in adjustments to process parameters that are based upon static, non-real time analysis. In yet another embodiment of the invention, the data analysis may result in adjustments to process parameters is a combination of both real time and static adjustments.

Sensor and parameter measurements may be filtered using a variety of techniques. Indeed, any technique known in the art may be used to filter the sensor and/or process measurements. According to one embodiment of the invention, at least one signal is received that corresponds to a quantity representing the purity or impurity of a chemical being
5 analyzed. The at least one signal may have a plurality of cycles and may have a frequency that varies over time. Filtering of the at least one signal may include bandpass filtering, which may be configured to remove harmonics and one or more low frequency components of the at least one signal. The filtered signal may be further processed in arriving at the desired filtered value. Filters imposed on the signal may include any one of or any
10 combination of an infinite impulse response (IIR) or a finite impulse response (FIR) filter for digital signal processing. FIR schemes having predictor schemes that attempt to estimate the actual signal value in the presence of induced noise on the signal. For example, a recursive FIR filter scheme having a variable order short term predictor that may be configured to adapt to a corrected actual signal value after the sensor noise has been eliminated from the
15 measurement is an advanced filter technique that may be employed.

Alternatively, analog filter processing may be used on the sensor device that may include any one or more of a Butterworth filter, a Chebyshev filter, an elliptic (Cauer) filter, a Bessel filter, a Gaussian filter, an optimum Legendre filter, and a Linkwitz–Riley filter. A Kalman filter that performs linear quadratic estimation on a series of measurements observed
20 over time may be used to eliminate statistical noise and other inaccuracies, and to produce an estimate that tends to be more accurate than those based on a single measurement alone.

According to an embodiment of the invention, a filtered and integrated sensor measurements comprising an absorbance of electromagnetic radiation data from a signal at least at one wavelength may have a wavelength being in a range of from about 100 to about
25 3000nm or from about 230 to about 1100 nm. Absorbance of electromagnetic radiation, i.e. ability of a chemical to absorb light, is a good indicator of the purity of a chemical. Therefore, absorbance is a good indicator of impurity in a wash or rinse solution.

According to a more advanced embodiment, absorbance is monitored at several discrete wavelengths, which can range from about 100 to about 3000 nm can range from
30 about 230 to about 1100 nm, or alternatively, at one or more wavelength ranges, whose lower and upper limits are within about 100 to about 3000 nm or within about 230 to about 1100 nm. By monitoring the absorbance at several discrete wavelengths or the total absorbance at all the wavelengths of a given wavelength range it is possible to indicate presence of a plurality of impurity factors in the feed and/or the return channels, whereby the difference in

the corresponding parameter sets indicates at several different wavelengths that the chemical still has a cleaning effect in the washing process.

A measurement of a sensor in a process plant tends to vary in accordance with at least one other process parameter measurement within the plant. An object of the invention is to
5 identify the at least one or more other process parameters that track the variation in the sensor measurement, and use measurements from these at least one or more process parameters representing process noise to help to correct the sensor noise.

In an embodiment of the invention, the correlation procedure provides a rate of change measurement on one or more process parameters to be easily made over a shorter data
10 acquisition interval. Any process noise identified in this rate of change measurement is then used to compensate for a comparable noise being experienced by the sensor measurement. Part of the correlation procedure in this exemplary embodiment is to separate any change in process condition from the changes in the process parameter from any change in the process parameter resulting from process noise. The latter is the change used in determining the
15 extent of correction to sensor noise being experienced in the sensor measurement.

In an embodiment of the invention, at least one of the sensor measurement and the process parameter is corrected according to at least one of in real time and statically.

Either the raw or filtered at least one signal, the signal representing a sensor and/or a parameter of the process, may be subjected to a correlation procedure involving resampling to
20 produce an even-angle signal. An even-angle signal is a resampled signal with a constant number of samples per revolution. Zero crossing detection may be performed on the filtered signal whereby start and end positions of each of the cycles in the first signal are detected. There may be two zero crossing points in each cycle of the at least one signal depending on the extent of resampling of the at least one signal that has occurred. For example, the
25 resampled signal may demonstrate a sinusoidal type pattern, The at least one signal having at least two zero crossing points has at least one rising edge and at least one falling edge. The start and end positions may be used to determine the even-angle positions of the first signal. More specifically, two adjacent zero crossing points may be the start and end position of a half cycle of the signal. According to the desired number of samples per cycle, the even
30 angle positions between every two zero crossing points may be calculated by linear interpolation. For example, if the desired number of samples is 200, there may be 100 even angle positions between two zero crossing points.

The zero crossing detection may be used to determine a fundamental frequency of the at least one signal. The fundamental frequency may be determined by calculating the time

difference between two zero crossing points, which may correspond to half the period ($1/(2 \times \text{frequency})$). A sampling rate (which may also be referred to as anti-aliasing parameters) may be determined based on the zero crossing detection. A new sampling rate may be the instantaneous fundamental frequency multiplied by the desired number of samples per cycle. For example, a 50 Hz fundamental frequency and 200 samples per cycle, according to Nyquist theory, the cut-off frequency of the filter is $200 \times 50 / 2$, which is 5000 Hz. This sampling rate may ensure that the even angle signal produced is not aliased. Of course any sensor or parameter collected from the process may be subjected to this type of correlation calculation.

Another signal correlation technique for a sensor and/or parameter may involve converting a measure value, preferably a series of measured values of the signal, into a vector signal having both a magnitude and phase that may be generated from the collection of at least one signal and/or parameter measurements taken. For example, an initial phase may be determined and the initial phase may be integrated to determine the instantaneous phase. The magnitude may also be the instantaneous magnitude that is determined. This determination may involve converting the real signal and the imaginary signal to the polar domain in order to determine the magnitude and phase (e.g., the instantaneous magnitude and the initial or instantaneous phase). This determination may be preceded by filtering the real signal and the imaginary signal to produce a filtered real signal and a filtered imaginary signal. For example, filtering the real signal and the imaginary signal may include performing low pass filtering of the real signal and the imaginary signal, which may remove harmonics and out of band components of the real signal and the imaginary signal.

Without intending to be bound by theory, in the angular domain, the fundamental of the signal may not vary in angular frequency so it may be much easier to isolate and analyze. Accordingly, frequency shifting may be performed to shift the fundamental component to DC, which introduces the real part and imaginary part.

Adaptive noise cancellation may be employed by isolating the noise from at least one parameter measured from the process, which is suspected of coinciding with the noise experienced by at least one sensor measurement. The noise isolated from the at least one parameter measured from the process may be appropriately scaled and then subtracted from the at least one sensor noise measurement. This technique also comprises using mathematical techniques, either statically or in real-time, to determine which parameter or parameters measured from the process correspond to the noise experienced by the corresponding sensor measurement. This mathematical technique will also determine the extent of scaling needed

to allow the parameter measurement noise correction to be adapted to match the relative gain of the corresponding sensor measurement. For example, such a technique may use a least-means-square (LMS) algorithm for adjusting coefficients of the filter to map the relative magnitude of the parameter measurement noise to that being experienced by the signal measurement.

Another aspect of the invention provides a method for filtering a sensor measurement. In an embodiment of the invention, the method for filtering a sensor measurement comprises the steps of receiving the sensor measurement from a process; measuring a process parameter from the process; evaluating if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element; analyzing whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition; and determining a process condition by filtering any identified sensor noise and any identified process noise. In certain embodiments of the invention, the sensor measurement is a sensor from at least one of a supply line of the process and an outlet line of the process. Further pursuant to this embodiment of the invention, depending upon the process configuration, the outlet line is a return line of the process.

In an embodiment of the invention, the process condition may comprise predicting the process condition. In another embodiment of the invention, the process may be controlled by using the sensor measurement that has been filtered.

In certain embodiments of the invention, determining the process condition comprises correcting the sensor measurement and the process parameter for any process noise that is identified.

In certain embodiments of the invention, the sensor noise element is caused by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical instability, a moisture influence, and a correlation error.

In an embodiment of the invention, the process may be an automated recirculation system. For example, an automated recirculation system may comprise any one of a CIP process, a bottle wash process, a crate wash process, a tunnel pasteurizer, a heating loop, a cooling loop, an evaporator, a membrane treatment process, an exterior filler cleaning system, a shrink tunnel, a fryer, a mechanical ware washing process. Non-limiting examples of causes for the sensor noise element is by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical instability, a moisture influence, and a correlation error.

In an embodiment of the invention, the automated recirculation system may comprise a CIP process. Further pursuant to this embodiment of the invention, the process noise element may be caused by any one or more of a foaming, a valve pulsing, a water hammering, a dip in signaling, a spike in signaling, a change in temperature, a change in process flow, a chemical reaction, and a dosing cleaning chemistry affect. Still further pursuant to this embodiment of the invention, the process parameter may include any one or more of a temperature, a pressure, a conductivity, a flow rate, a pH, a time, a total flow volume, a wash sequence step, an object being cleaned, a spectrophotometer, total organic carbon (TOC), adenosine triphosphate (ATP), redox potential (ORP), chemical oxygen demand (COD), biological oxygen demand (BOD), a detergent component concentration, a sanitizer component concentration, a pump signal, a valve signal, and a level.

In an embodiment of the invention, correcting the sensor measurement may comprise filtering an absorbance data from a sensor used to provide the analyzer measurement according to the procedures provided herein. Further pursuant to this embodiment of the invention, correcting the sensor measurement may additionally include integrating the absorbance data from the sensor with data from the process parameter.

Further pursuant to the embodiment of the invention, whereby the process is an automated recirculation system, the method for filtering the sensor measurement additional comprises the step of determining if a process step has completed based upon the filtered sensor measurement.

Further pursuant to the embodiment of the invention whereby the automated recirculation system is a CIP process, the method for filtering the sensor measurement may additionally comprise the step of determining an extent of cleaning of the process. In certain embodiments of the invention, when determining the extent of cleaning the process, the filtered sensor measurement comprises a soil concentration. Further pursuant to this embodiment of the invention, the extent of cleaning of the process comprises an extent of rinsing of the process.

In an embodiment of the invention, the method for filtering the sensor measurement may additionally comprise the steps of receiving another sensor measurement from the process; measuring another process parameter from the process; additionally evaluating if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise element; additionally analyzing whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an additional process noise

and the change in process condition; and determining the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise. Further pursuant to this embodiment of the invention, the sensor measurement and the process measurement are from a supply line of the process and the additional sensor measurement and the additional process measurement are from an outlet line of the process. In the embodiments of the invention when the process is an automated recirculation process, the outlet line is a return line of the process.

In an embodiment of the invention, an algorithm is used in determining whether at least one of the sensor noise element and the process noise element affects the sensor measurement in the method of filtering the sensor measurement. In a non-limiting example, the algorithm is used in determining whether at least one of the sensor noise element and the process noise element is affected by at least one of the sensor noise, the process noise and the change in process condition.

In an embodiment of the invention, the sensor noise element and the process noise element may comprise a low value and a high value that are used in analyzing whether any identified sensor noise element and process noise element is the result of at least one of the sensor noise, the process noise and the change in process condition.

In an embodiment of the invention, the method for filtering the sensor measurement may additionally comprise the steps obtaining an analyzer measurement using an analysis method; and evaluating if the analyzer measurement possesses an analysis method noise element, wherein analyzing whether any identified analysis method noise element is the result of an analysis method noise and determining the process condition additionally comprises filtering any identified analysis method noise. Further pursuant to this embodiment of the invention, the method for filtering the sensor measurement may additionally comprise the step of controlling the process using the sensor measurement that has been filtered.

In certain embodiments of the invention, determining the process condition comprises correcting the sensor measurement, the process parameter and the analysis method for any process noise that is identified.

Another aspect of the invention provides a measurement equipment to filter a sensor measurement, the measurement equipment comprising an interface for receiving a sensor measurement and a process measurement from a process, and a processor in communication with a memory, wherein the processor is configured to evaluate if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process

noise element; analyze whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition; and determine a process condition by filtering any identified sensor noise and any identified process noise. In certain embodiments of the invention, the processor is
5 additionally configured to control the process using the sensor measurement that has been filtered.

In an embodiment of the invention, the interface of the measurement equipment may additionally receive another sensor measurement from the process and receive another process parameter from the process. Further pursuant to this embodiment of the invention,
10 the processor is additionally configured evaluate if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise element, analyze whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an additional process noise and the change in process condition, and
15 determine the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise.

Based upon this embodiment of the invention, the sensor measurement and the process measurement are from a supply line of the process and the additional sensor
20 measurement and the additional process measurement are from an outlet line of the process. In this embodiment of the invention, the process may be an automated recirculation system and the outlet line is a return line of the process, according to this embodiment of the invention.

In certain embodiments of the invention, the processor uses an algorithm to determine
25 whether at least one of the sensor noise element and the process noise element affects the sensor measurement.

In yet another aspect of the invention, a system to filter a sensor measurement is provided. The system to filter a sensor measurement comprises an interface that receives a sensor measurement and a process measurement from a process, and a processor in
30 communication with a memory, wherein the processor evaluates if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element; analyzes whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process

condition; and determines a process condition by filtering any identified sensor noise and any identified process noise.

5 Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the descriptions herein. It will be appreciated by those skilled in the art that changes could be made to the embodiments described herein without departing from the broad inventive concept thereof. Therefore, it is understood that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications within the spirit and scope of the present invention as defined by the included claims.

CLAIMS

That which is claimed:

1. A method for filtering a sensor measurement comprising:
 - receiving the sensor measurement from a process;
 - 5 - measuring a process parameter from the process;
 - evaluating if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element;
 - analyzing whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition;
 - 10 and
 - determining a process condition by filtering any identified sensor noise and any identified process noise.
2. The method of claim 1, wherein the sensor measurement is a sensor from at least one of a supply line of the process and an outlet line of the process.
- 15 3. The method of claim 2, wherein the outlet line is a return line of the process.
4. The method of claim 1, wherein determining the process condition comprises predicting the process condition.
5. The method of claim 1, additionally comprising controlling the process using the sensor measurement that has been filtered.
- 20 6. The method of claim 1, wherein determining the process condition comprises correcting the sensor measurement and the process parameter for any process noise that is identified.
7. The method of claim 1, wherein the sensor noise element is caused by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical
25 instability, a moisture influence, and a correlation error.
8. The method of claim 1, wherein the process is an automated recirculation system.
9. The method of claim 8, wherein the automated recirculation system comprises any one of a clean-in-place (CIP) process, a bottle wash process, a crate wash process, a tunnel

pasteurizer, a heating loop, a cooling loop, an evaporator, a membrane treatment process, an exterior filler cleaning system, a shrink tunnel, a fryer, a mechanical ware washing process.

10. The method of claim 8, wherein the sensor noise element is caused by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical
5 instability, a moisture influence, and a correlation error.

11. The method of claim 9, wherein the automated recirculation system comprises the CIP process.

12. The method of claim 11, wherein the process noise element is caused by any one or more of a foaming, a valve pulsing, a water hammering, a dip in signaling, a spike in
10 signaling, a change in temperature, a change in process flow, a chemical reaction, and a dosing cleaning chemistry affect.

13. The method of claim 11, wherein the process parameter comprises any one or more of a temperature, a pressure, a conductivity, a flow rate, a pH, a time, a total flow volume, a wash sequence step, an object being cleaned, a spectrophotometer, total organic carbon
15 (TOC), adenosine triphosphate (ATP), redox potential (ORP), chemical oxygen demand (COD), biological oxygen demand (BOD), a detergent component concentration, a sanitizer component concentration, a pump signal, a valve signal, and a level.

14. The method of claim 1, wherein correcting the sensor measurement comprises filtering an absorbance data from a sensor used to provide the analyzer measurement.

20 15. The method of claim 14, wherein the absorbance data includes absorbance of electromagnetic radiation or a quantity derived therefrom at least at one wavelength, the wavelength being within a range of about 100 to about 3000 nm.

16. The method of claim 15, wherein the wavelength being within a range of about 230 to about 1100 nm.

25 17. The method of claim 14, wherein the absorbance data includes absorbance of electromagnetic radiation or a quantity derived therefrom at a plurality of discrete wavelengths within a range of about 100 to about 3000 nm.

18. The method of claim 17, wherein the plurality of discrete wavelengths is within a range of about 230 to about 1100 nm.

19. The method of claim 14, wherein the absorbance data includes a total absorbance of electromagnetic radiation or a quantity derived therefrom at least in one wavelength range having an upper limit and a lower limit within a range of about 100 and about 3000 nm.
20. The method of claim 19, wherein the at least in one wavelength range having an upper
5 limit and a lower limit within a range of about 230 and about 1100 nm.
21. The method of claim 14, wherein correcting the sensor measurement additionally comprises integrating the absorbance data from the sensor with data from the process parameter.
22. The method of claim 8, additionally comprising determining if a process step has
10 completed.
23. The method of claim 11, additionally comprising determining an extent of cleaning of the process.
24. The method of claim 23, wherein the extent of cleaning of the process comprises an extent of rinsing of the process.
- 15 25. The method of claim 6, wherein at least one of the sensor measurement and the process parameter is corrected according to at least one of in real time and statically.
26. The method of claim 1, additionally comprising
- receiving another sensor measurement from the process;
 - measuring another process parameter from the process;
 - 20 - additionally evaluating if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise element;
 - additionally analyzing whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an
25 additional process noise and the change in process condition; and
 - determining the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise.

27. The method of claim 26, wherein the sensor measurement and the process measurement are from a supply line of the process and the additional sensor measurement and the additional process measurement are from an outlet line of the process.

28. The method of claim 27, wherein the process is an automated recirculation system and the outlet line is a return line of the process.

29. The method of claim 1, wherein an algorithm is used in determining whether at least one of the sensor noise element and the process noise element affects the sensor measurement.

30. The method of claim 29, wherein the algorithm is used in determining whether at least one of the sensor noise element and the process noise element is affected by at least one of the sensor noise, the process noise and the change in process condition.

31. The method of claim 1, wherein the sensor noise element and the process noise element comprise a low value and a high value that are used in analyzing whether any identified sensor noise element and process noise element is the result of at least one of the sensor noise, the process noise and the change in process condition.

32. The method of claim 1, additionally comprising
- obtaining an analyzer measurement using an analysis method; and
- evaluating if the analyzer measurement possesses an analysis method noise element, wherein analyzing whether any identified analysis method noise element is the result of an analysis method noise and determining the process condition additionally comprises filtering any identified analysis method noise.

33. The method of claim 32, additionally comprising controlling the process using the sensor measurement that has been filtered.

34. The method of claim 32, wherein determining the process condition comprises correcting the sensor measurement, the process parameter and the analysis method for any process noise that is identified.

35. A measurement equipment for filtering a sensor measurement comprising:
- an interface that receives a sensor measurement and a process measurement from a process; and
- a processor in communication with a memory,

wherein the processor is configured to:

- evaluate if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element;
- analyze whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition; and
- determine a process condition by filtering any identified sensor noise and any identified process noise.

36. The measurement equipment of claim 35, wherein the processor is additionally configured to control the process using the sensor measurement that has been filtered.

37. The measurement equipment of claim 35, wherein the interface additionally receives another sensor measurement from the process and another process parameter from the process and wherein the processor is additionally configured to:

- evaluate if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise element;

- analyze whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an additional process noise and the change in process condition; and

- determine the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise.

38. The measurement equipment of claim 37, wherein the sensor measurement and the process measurement are from a supply line of the process and the additional sensor measurement and the additional process measurement are from an outlet line of the process.

39. The measurement equipment of claim 38, wherein the process is an automated recirculation system.

40. The measurement equipment of claim 39, wherein the outlet line is a return line of the process.

41. The measurement equipment of claim 35, wherein the processor uses an algorithm to determine whether at least one of the sensor noise element and the process noise element affects the sensor measurement.

42. A system to filter a sensor measurement comprising:
- an interface that receives a sensor measurement and a process measurement from a process; and
 - a processor in communication with a memory,
- 5 wherein the processor:
- evaluates if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element;
 - analyzes whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition;
- 10 and
- determines a process condition by filtering any identified sensor noise and any identified process noise.

AMENDED CLAIMS

received by the International Bureau on 4 February 2019 (04.02.2019)

That which is claimed:

1. A method for filtering a sensor measurement comprising:
 - receiving the sensor measurement from a manufacturing or process plant;
 - measuring a process parameter from the manufacturing or process plant;
 - evaluating if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element;
 - analyzing whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition;
 - filtering any identified sensor noise and any identified process noise; and
 - using the filtered identified sensor noise and the filtered identified process noise to identify the change in process condition that resulted in any identified sensor noise element and process noise element.
2. The method of claim 1, wherein the sensor measurement is a sensor from at least one of a supply line of the manufacturing or process plant and an outlet line of the manufacturing or process plant.
3. The method of claim 2, wherein the outlet line is a return line of the manufacturing or process plant.
4. The method of claim 1, wherein determining the process condition comprises predicting the process condition.
5. The method of claim 1, additionally comprising controlling the manufacturing or process plant using the sensor measurement that has been filtered.
6. The method of claim 1, wherein determining the process condition comprises correcting the sensor measurement and the process parameter for any process noise that is identified.
7. The method of claim 1, wherein the sensor noise element is caused by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical instability, a moisture influence, and a correlation error.

8. The method of claim 1, wherein the manufacturing or process plant is an automated recirculation system.
9. The method of claim 8, wherein the automated recirculation system comprises any one of a clean-in-place (CIP) process, a bottle wash process, a crate wash process, a tunnel pasteurizer, a heating loop, a cooling loop, an evaporator, a membrane treatment process, an exterior filler cleaning system, a shrink tunnel, a fryer, a mechanical ware washing process.
10. The method of claim 8, wherein the sensor noise element is caused by any one or more of a quantization, an electromagnetic interference, a calibration error, a mechanical instability, a moisture influence, and a correlation error.
11. The method of claim 9, wherein the automated recirculation system comprises the CIP process.
12. The method of claim 11, wherein the process noise element is caused by any one or more of a foaming, a valve pulsing, a water hammering, a dip in signaling, a spike in signaling, a change in temperature, a change in process flow, a chemical reaction, and a dosing cleaning chemistry affect.
13. The method of claim 11, wherein the process parameter comprises any one or more of a temperature, a pressure, a conductivity, a flow rate, a pH, a time, a total flow volume, a wash sequence step, an object being cleaned, a spectrophotometer, total organic carbon (TOC), adenosine triphosphate (ATP), redox potential (ORP), chemical oxygen demand (COD), biological oxygen demand (BOD), a detergent component concentration, a sanitizer component concentration, a pump signal, a valve signal, and a level.
14. The method of claim 1, wherein correcting the sensor measurement comprises filtering an absorbance data from a sensor used to provide the analyzer measurement.
15. The method of claim 14, wherein the absorbance data includes absorbance of electromagnetic radiation or a quantity derived therefrom at least at one wavelength, the wavelength being within a range of about 100 to about 3000 nm.

16. The method of claim 15, wherein the wavelength being within a range of about 230 to about 1100 nm.
17. The method of claim 14, wherein the absorbance data includes absorbance of electromagnetic radiation or a quantity derived therefrom at a plurality of discrete wavelengths within a range of about 100 to about 3000 nm.
18. The method of claim 17, wherein the plurality of discrete wavelengths is within a range of about 230 to about 1100 nm.
19. The method of claim 14, wherein the absorbance data includes a total absorbance of electromagnetic radiation or a quantity derived therefrom at least in one wavelength range having an upper limit and a lower limit within a range of about 100 and about 3000 nm.
20. The method of claim 19, wherein the at least in one wavelength range having an upper limit and a lower limit within a range of about 230 and about 1100 nm.
21. The method of claim 14, wherein correcting the sensor measurement additionally comprises integrating the absorbance data from the sensor with data from the process parameter.
22. The method of claim 8, additionally comprising determining if a process step has completed.
23. The method of claim 11, additionally comprising determining an extent of cleaning of the manufacturing or process plant.
24. The method of claim 23, wherein the extent of cleaning of the manufacturing or process plant comprises an extent of rinsing of the manufacturing or process plant.
25. The method of claim 6, wherein at least one of the sensor measurement and the process parameter is corrected according to at least one of in real time and statically.
26. The method of claim 1, additionally comprising
 - receiving another sensor measurement from the manufacturing or process plant;
 - measuring another process parameter from the manufacturing or process plant;

- additionally evaluating if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise element;

- additionally analyzing whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an additional process noise and the change in process condition; and

- determining the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise.

27. The method of claim 26, wherein the sensor measurement and the process measurement are from a supply line of the process and the additional sensor measurement and the additional process measurement are from an outlet line of the manufacturing or process plant.

28. The method of claim 27, wherein the process is an automated recirculation system and the outlet line is a return line of the manufacturing or process plant.

29. The method of claim 1, wherein an algorithm is used in determining whether at least one of the sensor noise element and the process noise element affects the sensor measurement.

30. The method of claim 29, wherein the algorithm is used in determining whether at least one of the sensor noise element and the process noise element is affected by at least one of the sensor noise, the process noise and the change in process condition.

31. The method of claim 1, wherein the sensor noise element and the process noise element comprise a low value and a high value that are used in analyzing whether any identified sensor noise element and process noise element is the result of at least one of the sensor noise, the process noise and the change in process condition.

32. The method of claim 1, additionally comprising

- obtaining an analyzer measurement using an analysis method; and
- evaluating if the analyzer measurement possesses an analysis method noise element, wherein analyzing whether any identified analysis method noise element is the result of an analysis method noise and determining a process condition additionally comprises filtering any identified analysis method noise.

33. The method of claim 32, additionally comprising controlling a manufacturing or process plant using the sensor measurement that has been filtered.

34. The method of claim 32, wherein determining the process condition comprises correcting the sensor measurement, the process parameter and the analysis method for any process noise that is identified.

35. A measurement equipment for filtering a sensor measurement comprising:

- an interface that receives the sensor measurement and a process measurement from a manufacturing or process plant; and

- a processor in communication with a memory,

wherein the processor is configured to:

- evaluate if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element;

- analyze whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition;

- filter any identified sensor noise and any identified process noise; and

- use the filtered identified sensor noise and the filtered identified process noise to identify the change in process condition that resulted in any identified sensor noise element and process noise element.

36. The measurement equipment of claim 35, wherein the processor is additionally configured to control the manufacturing or process plant using the sensor measurement that has been filtered.

37. The measurement equipment of claim 35, wherein the interface additionally receives another sensor measurement from the process and another process parameter from the manufacturing or process plant and wherein the processor is additionally configured to:

- evaluate if at least one of the another sensor measurement possesses an additional sensor noise element and the another process parameter possesses an additional process noise element;

- analyze whether any identified additional sensor noise element and additional process noise element is the result of at least one of an additional sensor noise, an additional process noise and the change in process condition; and

- determine the process condition by filtering any identified sensor noise, any identified additional sensor noises, any identified process noise and any identified additional process noise.

38. The measurement equipment of claim 37, wherein the sensor measurement and the process measurement are from a supply line of the manufacturing or process plant and the additional sensor measurement and the additional process measurement are from an outlet line of the manufacturing or process plant.

39. The measurement equipment of claim 38, wherein the manufacturing or process plant is an automated recirculation system.

40. The measurement equipment of claim 39, wherein the outlet line is a return line of the manufacturing or process plant.

41. The measurement equipment of claim 35, wherein the processor uses an algorithm to determine whether at least one of the sensor noise element and the process noise element affects the sensor measurement.

42. A system to filter a sensor measurement comprising:

- an interface that receives the sensor measurement and a process measurement from a manufacturing or process plant; and

- a processor in communication with a memory,

wherein the processor:

- evaluates if at least one of the sensor measurement possesses a sensor noise element and the process parameter possesses a process noise element;

- analyzes whether any identified sensor noise element and process noise element is the result of at least one of a sensor noise, a process noise and a change in process condition;

- determines a process condition by filtering any identified sensor noise and any identified process noise; and

- uses the filtered identified sensor noise and the filtered identified process noise to identify the change in process condition that resulted in any identified sensor noise element and process noise element.

STATEMENT UNDER ARTICLE 19 (1)

The invention is directed to filtering a sensor measurement in a manufacturing or process plant. While the Examiner admits that the claims are novel, the Examiner alleges the claims lack inventive step primarily for the reason that the Examiner interprets “process” as an abstract term corresponding to a method alleging the term is void of technical character. Furthermore, the Examiner alleges the terms “process parameter”, “process noise”, “process noise element”, “process condition” and “change in process condition” define aspects of the process feature that makes themselves devoid of technical character. Finally, the Examiner concludes that “determining a process condition” correspondingly is devoid of technical character.

The claims have been amended to make it clear that they now refer to a manufacturing or process plant and not a process the Examiner refers to as an abstract term. The amendments to the claims overcome the objections raised by the Examiner.

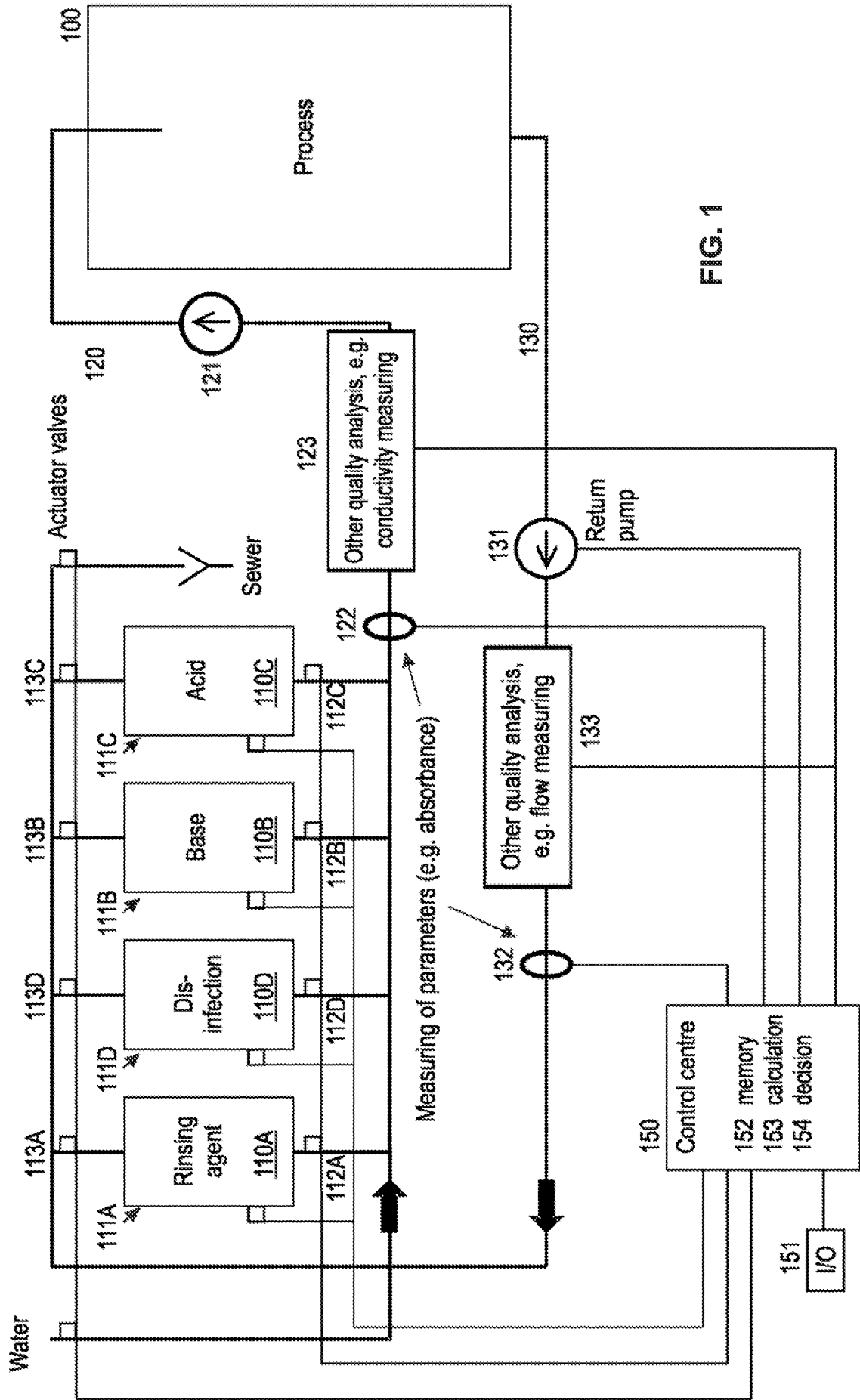
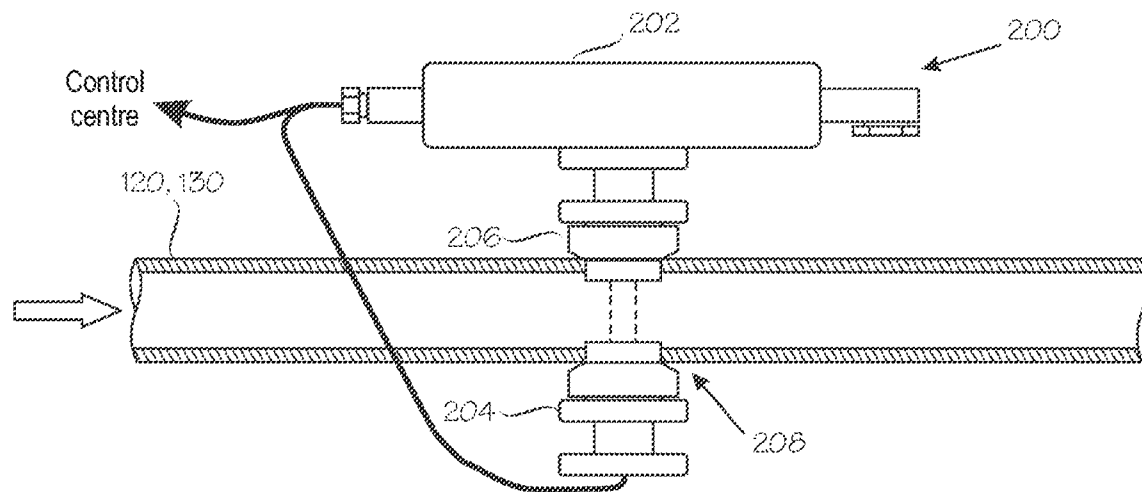
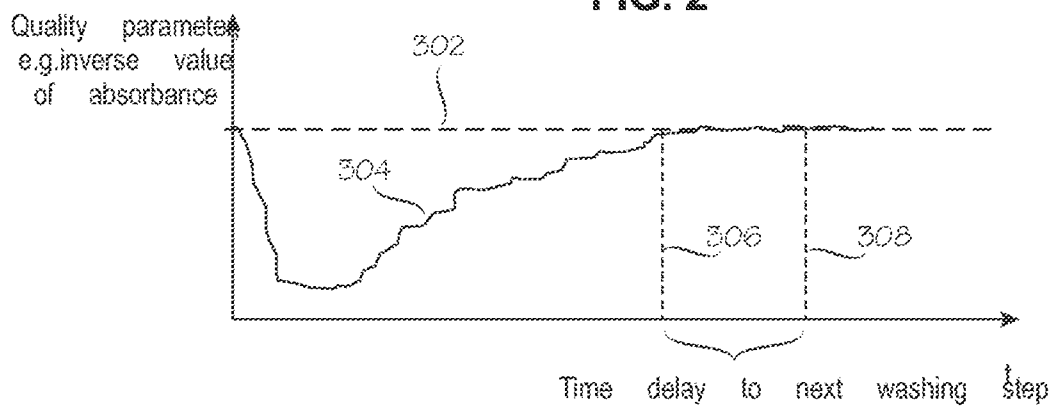
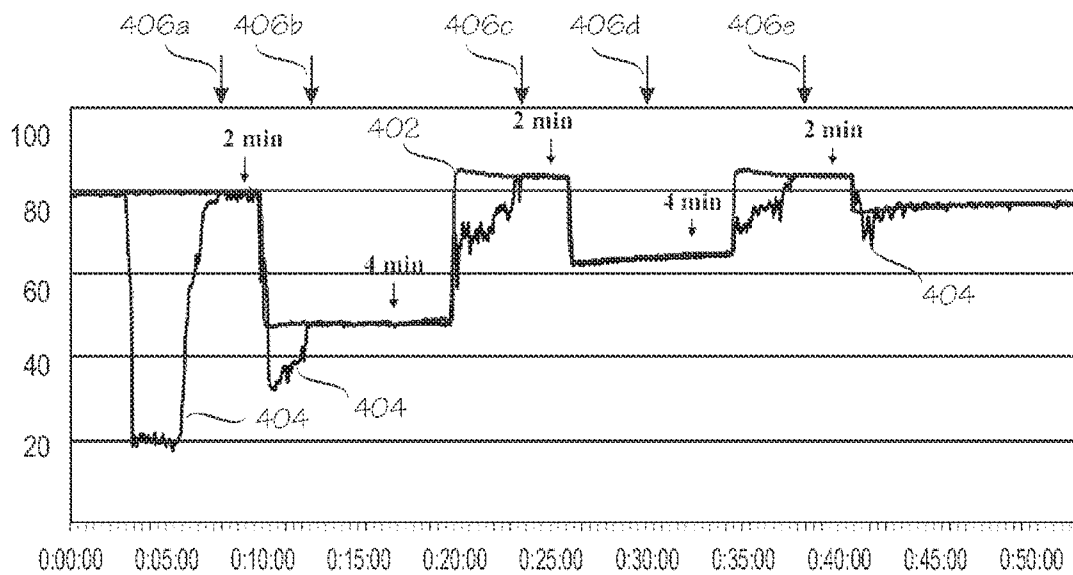


FIG. 1

**FIG. 2****FIG. 3****FIG. 4**

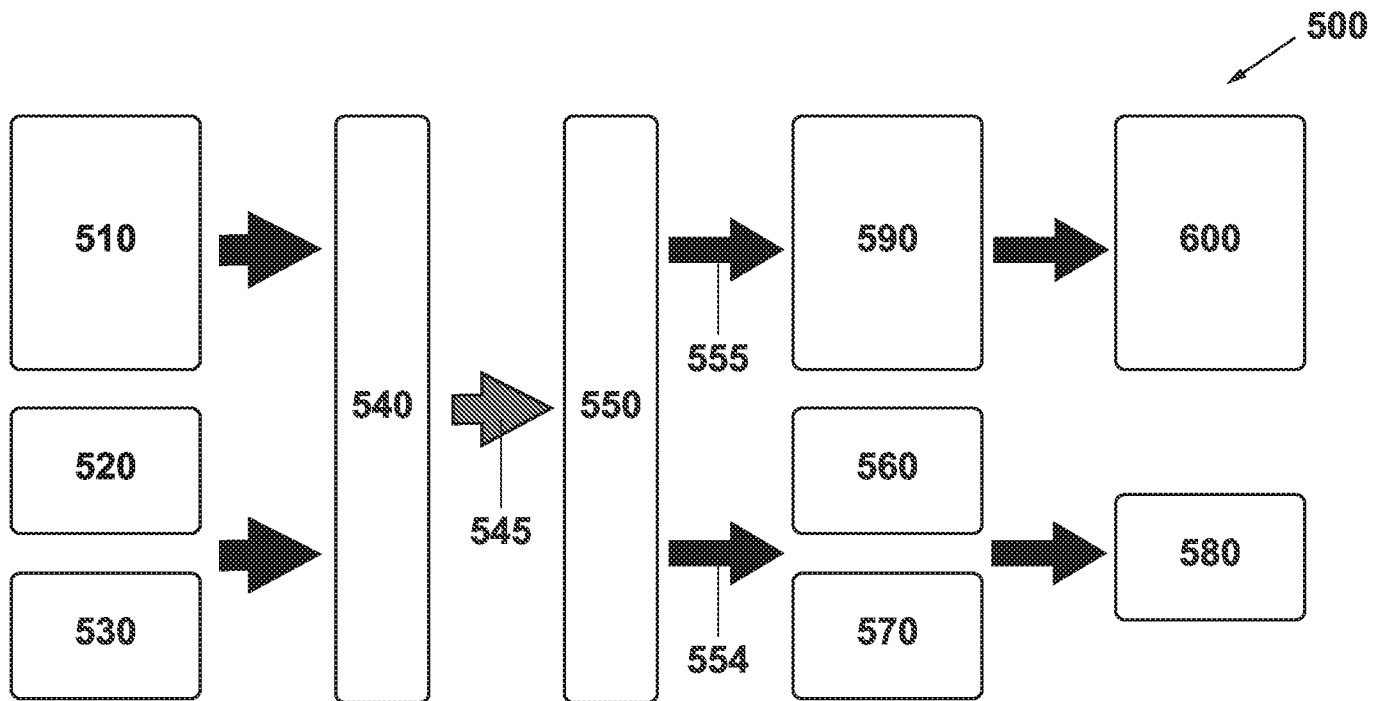


FIG. 5

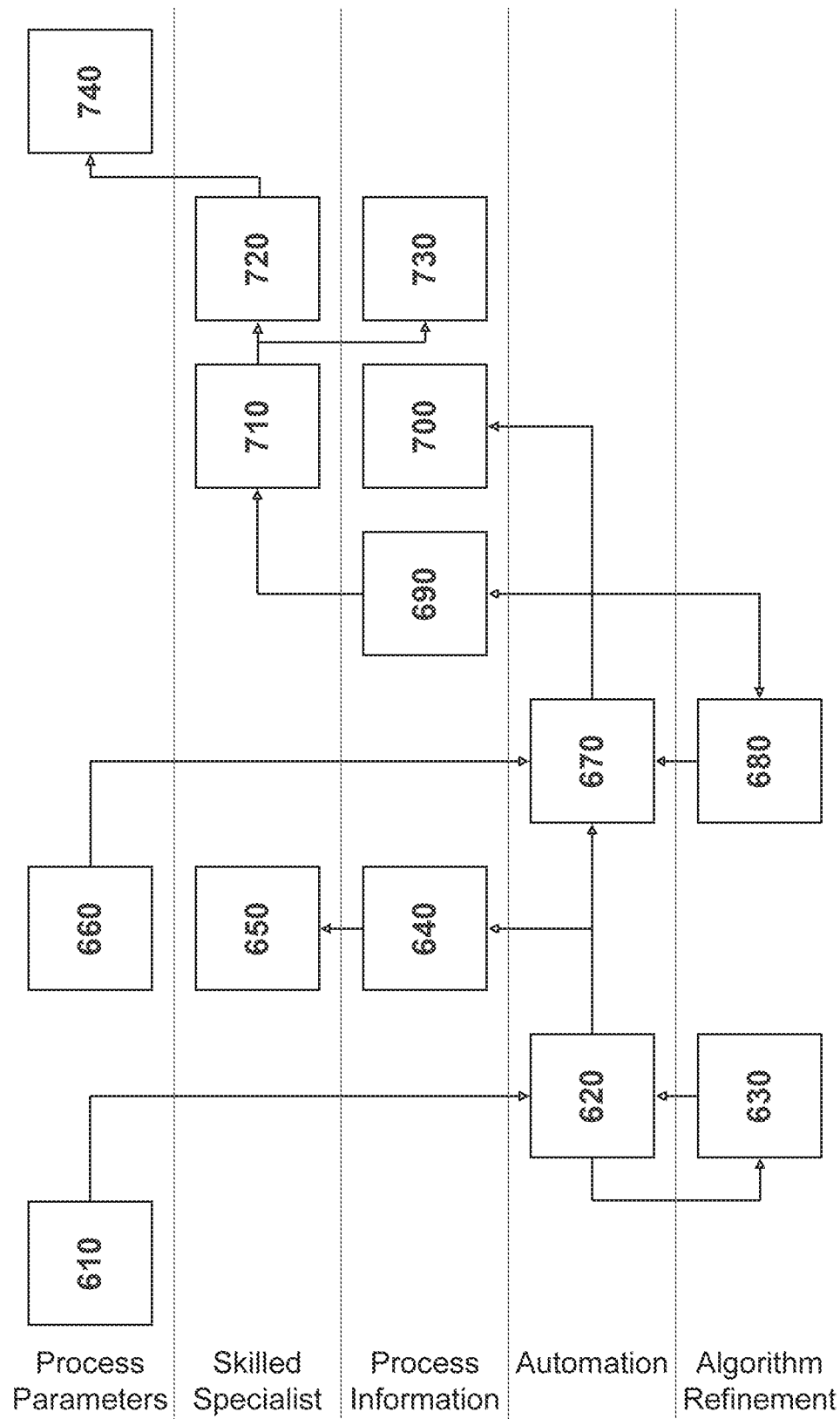


FIG. 6

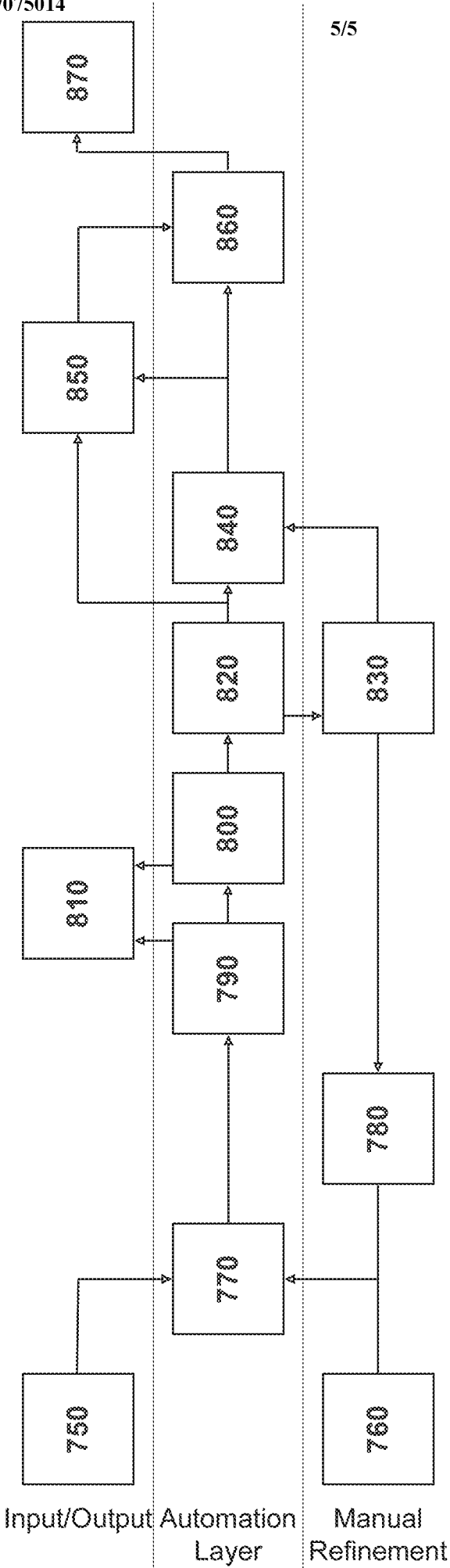


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/055150

A. CLASSIFICATION OF SUBJECT MATTER

INV. D06F39/02 D06F39/08 D06F31/00 D06F33/02
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)
D06F

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 2013/048024 A1 (PAHLMAN TUOMAS [FI]) 28 February 2013 (2013-02-28) figure 1 paragraphs [0032] - [0040] -----	1-42



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"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

4 December 2018

Date of mailing of the international search report

13/12/2018

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/055150

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013048024 A1	28-02-2013	US 2013048024 A1	28-02-2013
		US 2017231458 A1	17-08-2017
