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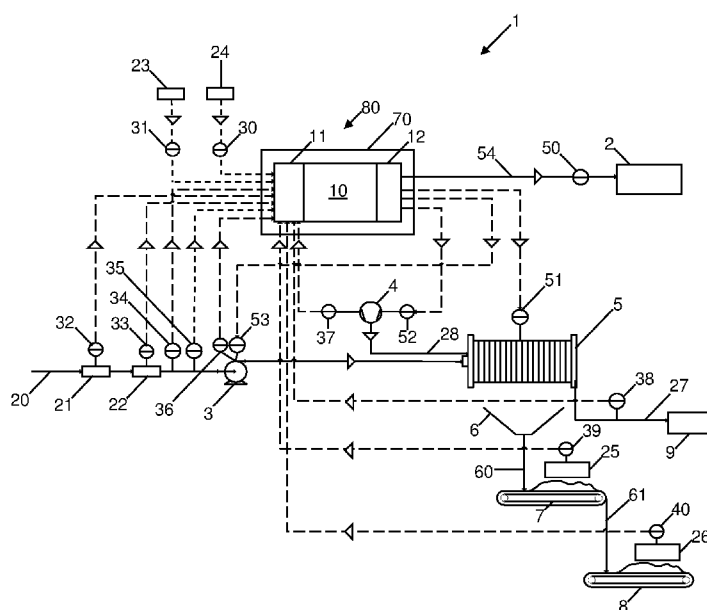


FIG. 1

(57) Abstract: The disclosure relates to a method of controlling a filtration process using a filter (5), and further relates to a filtration system (1). The method employs predictive and/or adaptive learning protocols to initialize and reinitialize control set points for filtration parameters of a filter (5) over time. Inputs (11) are received by an operating algorithm (10) and are processed to deliver a number of outputs (12) including instructions which may include the adjustment of one or more control set points which affect the operation and/or performance of the filter (5). The control set points may be altered, in response to changing inputs (11), in order to achieve the most efficient run settings for a filter (5), whilst still maintaining or exceeding target cake product (60, 61) specifications.

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SYSTEM AND METHOD FOR PREDICTIVE AND ADAPTIVE FILTERING AND APPARATUS THEREOF

FIELD OF THE INVENTION

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This application pertains to industrial filtration equipment applicable for use in the chemical, waste-water treatment, pulp and paper, and mining industries (e.g., concentrator operations, ore dressing, tailings management, and mineral processing).

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Particularly disclosed are novel methods and apparatus for automatically predicting how certain operational inputs, feed process variables, and filtration parameters within a filtration process might affect filter cake moisture, density, or another characteristic thereof. Further disclosed are novel methods and apparatus for automatically making predictive and adaptive changes to a filtration process, based on real-time learning techniques and past observations.

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Filtration operations may realize an immediate benefit from practicing embodiments of the invention, which are aimed towards improving filtration processes, such as vacuum and pressure filtration processes. Embodiments of the invention may promote economic dewatering of feed slurries by increasing operating efficiencies without incurring significant capital expenditure (CAPEX).

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Industrial operations having one or more filtration machines, or one or more banks of filters may especially recognize advantages through the provision, employment, and operational use of multiple systems and apparatus disclosed herein. It will become apparent from this disclosure that practicing any number of the method steps described herein might offer various advantages and benefits not yet available with conventional filtration technologies.

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BACKGROUND OF THE DISCLOSURE

Industrial filters may use vacuum or pressure to de-liquor or extract liquids from slurry material and form a filter cake product. Filter presses (such as horizontal
5 automatic filter presses) use pressure and are used in separation processes - specifically to separate solids and liquids. The filtration process for a filter press uses the principle of "pressure driving" by a slurry pump. Filter presses have many uses in the industrial, chemical, pharma, and wine-making industries. They may be utilized to separate water from mud or to dewater tailings and/or mineral
10 mining slurries, without limitation.

Types of filter presses may include plate and frame filter presses, automatic filter presses, and recessed plate, membrane plate, and frame filter presses. Filter presses can come in various configurations, such as in vertical and horizontal
15 configurations, with horizontal being the most widely used. Three main process characteristics of filter presses include feed, operation, and efficiency.

Filter automation has traditionally been programmed using control set points which may be selected by an operator of a filter and initialized in advance of a
20 large number of repetitive filtration cycles. These operator-settable control set points are generally initialized once, upfront, and then remain fixed for a number of cycles (i.e., from cycle to cycle and between successive cycles), and are rarely changed throughout a filtration process. Infrequent changes to control set points within very dynamic filtration processes having greatly varying feed conditions
25 can wreak havoc to filter cake consistency and/or quality.

Control set points are traditionally initialized to control certain operating parameters of a filter, such as: the feed pump filling time/duration, feed slurry pressure, whether or not to use an air blow cycle (e.g., cake air blow "on/off"
30 Boolean logic value), the amount of air blow or air blow duration time used for cake drying (e.g., if air blow value is set to "on"), the air blow pressure used for

cake drying (e.g., if air blow value is set to "on"), whether or not to use a membrane squeeze cycle (e.g., membrane squeeze "on/off" Boolean logic value), the membrane squeeze time (e.g., if membrane squeeze value is set to "on"), and the membrane plate inflation pressure (e.g., if membrane squeeze
5 value is set to "on"), without limitation.

Usually, the time duration settings relating to each of these control set points is generally determined in advance of full scale operation, through smaller bench-scale testing. For example, the feed pump filling time duration for an industrial
10 filtering operation may be determined by first manually measuring cake moisture of a dried (e.g., de-liquored/de-watered) cake produced by a smaller-scale bench scale filter press and then determining a sufficient feed pump filling time duration for the full scale filter (after "sizing-up" the smaller-scale test model). As another example, the air blow and/or membrane squeeze timers of an industrial filtering
15 operation may be set manually – or set to zero (i.e., "off"), based on data which was previously procured through smaller-scale bench testing.

Some common problems found with conventional prior art filter presses are as follows:

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Firstly, state-of-the-art feed pump filling duration timers currently operate with a fixed preset value, and therefore, they do not adapt or change (nor are they configured to adapt/change) when there are significant changes in feed solids density, particle size distribution, or mineralogy. Accordingly, state-of-the-art
25 feed pump duration timers are ill-equipped to handle changing feed characteristics, as they are not configured to automatically change feed pump filling duration for an individual filtration cycle, or between successive filtration cycles without manual human intervention.

30 Accordingly, with conventional filters, an operator must determine, in advance, the best setting, combination of settings, and/or operating control set point values

to run a filtering machine at. While the operator may, of course, *manually* change one or more operating control set point values during a filtering operation, it would be quite onerous for an operator to continuously manually adjust filtration control settings for every filtration cycle (of every filter within a
5 filtration process). Secondly, it would require much guesswork, where intuition and experience can vary wildly between different human operators. Since, with prior technologies, many filtration cycles might be completed before filtration parameters are appropriately corrected, cake product consistency and/or quality may vary wildly with abrupt changes in feed slurry characteristics. Such changes
10 in feed slurry characteristics may include, for example, changes in: mineral content/mineralogy (e.g., clay content), temperature, viscosity, particle size distribution (PSD), material composition, density, compactability or compressibility of the solids in the feed material, etc.).

15 Secondly, due to constant changes in feed slurry characteristics (due to diversity and randomness in mineral veins, lodes, and ore body being mined), cake air blow and/or membrane squeeze steps may not always be recommended or necessary for a given filtration cycle, in order to successfully obtain a target cake moisture and/or density in a finalized cake product.

20 Currently, if ore body being mined changes to the extent that cake air blow and/or membrane squeeze steps are needed to produce a cake meeting target cake moisture and/or density specifications, then the activation of these aforementioned functions must be performed manually (along with the
25 programming of a control set point timer(s) which controls the amount of time that each function will take to complete and/or a pressure set point(s) which controls amount of pressure that each function will be performed at). They must also be deactivated manually. This can unnecessarily burden an operator with a lot of guesswork in constantly obtaining the most economical and effective filter control
30 settings of a filtration process in real-time, given the many frequently-changing input variables to that filtration process.

Thirdly, in most plants employing a filtration operation to date, the detection of problems with cake consolidation time, cake air blow time, and/or membrane squeeze time generally occurs only *after* the filter cake has already been discharged from a filter (i.e., downstream of the filter). This means that an operator may have to determine the outcome of a load or two of “off spec” cake material being conveyed away from the filter after-the-fact. This determination step could involve intense manual intervention with other machinery before the defective dried product can be transferred to its final destination or accepted for its intended use, and filtration operations can resume.

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Fourthly, since most industrial filters involve a fixed process based on the assumption of having a relatively consistent fixed composition feed, any variation in feed process variables (e.g., particle size distribution, mineralogy, or density) pertaining to the feed slurry can possibly lead to an inconsistent cake product being discharged from the filter.

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While various solutions have been proposed in an attempt to overcome the aforementioned problems, there still exists a need for filtration technologies which might improve industrial filtration operations and increase process performance whilst reducing the following: human interpolation error, manual control setting errors, cost of operations/operating expenditures (OPEX), occurrences of poorly set-operational filtration parameters, occurrences off-spec cake, and frequent or constant inefficient use of certain sometimes unnecessary operational steps (e.g., cake air blow, membrane squeeze, etc.), without limitation.

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There further exists a need for filtration technologies which improve filter press operating efficiency, reduce emissions/carbon footprint, produce a higher quality (i.e., more consistent/homogenous) filter cake product, allow an operator to more precisely control the filtering process without manual intervention, and maintain desired/targeted cake product specifications -- regardless of changing or

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unpredictable environmental conditions (e.g., weather, rain, snow, fog, relative humidity, dew point, etc.) and/or regardless of changing or unpredictable feed process variables (e.g., mineralogy, particle size distribution, density, etc.).

5 OBJECTS OF THE INVENTION

It is, therefore, an object of the invention to circumvent the aforementioned drawbacks and challenges associated with prior art filtering devices.

- 10 In particular, it is an object of the invention to enable a filter to produce quality filter cake product in the most efficient manner possible.

It also an object of the invention to provide the ability to gather, store, access, and capitalize on useful data which may help develop and advance filtration
15 algorithms through data analytics.

It also an object of the invention to enable better filter control and provide plant operations with “big data”- and/or “internet of things” (IOT)-based pressure filters – including, but not limited to, IOT-based horizontal automatic filter presses,
20 without limitation.

The disclosed predictive and preferably adaptive control protocols for a filtration system aim to provide an industrial filtering device with the capability of automatically operating without the use of fixed timers, and with the added
25 benefits of potentially shortened cycle times, potentially better efficiency, and potentially more consistent cake products.

The disclosed predictive and preferably adaptive filter control system 80 further aims to configure an industrial filtering device 5 to be able to automatically
30 operate and deploy additional optional steps, in real-time, and as necessary, to one or more filtration cycles during operation, depending on certain inputs 11

received (e.g., variables relating to incoming feed slurry 20, filter cake 60, 61 produced, and/or current filtration parameter set points being used for a filter 5).

Intermittent addition of an optional membrane squeeze step and/or an optional cake air blow step to a filtration cycle, may be performed during filter operation preferably only when it is necessary to achieve certain target product specifications. For example, the use of an optional membrane squeeze step and/or an optional cake air blow step may be performed during a filtration cycle if required to meet or exceed a target cake moisture or cake density specification.

As process conditions change over time (e.g., changes in local weather/environment, feed characteristics, etc.), the use of these optional steps may vary and may change over time.

In other words, if a filter cake 60, 61 being produced by a filtering device does not meet certain desired target cake moisture and/or target cake density requirements through cake consolidation alone during a normal filtration cycle, the novel methods, system, and apparatus described herein may be practiced in order to automatically deploy additional steps or make process control changes which ensure that desired target cake product specifications are more closely approached, met, and/or exceeded – regardless of constantly-changing feed process variables. Deployment of these additional steps or process control changes may be dictated by or otherwise governed by an operating algorithm 10 which may static or configured to dynamically develop over time, based upon adaptive learning protocols, on-line data accumulation, and data analytics. The operating algorithm 10 may interpret and process a number of changing inputs 11, and deliver a number of outputs 12, which may involve instructions for changing one or more operational filtration parameters (e.g., instructions for adjusting control set points within a control system 80 of a filtration system 1 comprising a filter 5 which is in operation, without limitation).

This and other objects of the invention will be apparent from the drawings and description herein. Although every object of the invention is believed to be attained by at least one embodiment of the invention, there is not necessarily any one embodiment of the invention that achieves all of the objects of the invention.

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BRIEF SUMMARY OF THE INVENTION

Disclosed, is a method of controlling a filtration process utilizing a filter 5 (e.g., a filter press, without limitation). The method may comprise the steps of:

10 establishing a target filter cake moisture value for filter cake 60, 61 to be produced by the filtration process; feeding slurry 20 to the filter 5 via a pump 3; initializing one or more control set points pertaining to filtration parameters selected from the group consisting of: feed slurry flow rate, feed slurry pressure, feed temperature, feed slurry fill time, cake air blow on/off Boolean logic value,

15 cake air blow pressure, cake air blow time, membrane squeeze on/off Boolean logic value, membrane plate inflation pressure, membrane plate inflation time; and conveyor 7, 8 belt speed; dewatering the slurry 20 using the filter 5 during the first filtration cycle; forming a filter cake 60 using the filter 5 during the first filtration cycle; and, discharging the filter cake 60 from the filter 5 during the first

20 filtration cycle, without limitation.

The method may further comprise the adaptive step of analyzing the filter cake 60 formed during the first filtration cycle to determine a first actual filter cake moisture value for filter cake 60, 61 produced during the first filtration cycle. The

25 target filter cake moisture value for the filter cake 60, 61 and/or the first actual filter cake moisture value for filter cake 60, 61 may relate to a liquids fraction of the filter cake 60, 61 intended for production or actually produced, respectively; and the values of each may be represented as a weight percent (wt%) or volume percent (vol%) liquid as a matter of choice, without limitation.

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The method may further comprise the adaptive step of comparing the first actual filter cake moisture value with the established target filter cake moisture value, to determine a first target difference value therebetween; wherein the first target difference value may comprise the difference between the first actual filter cake moisture value and the established target filter cake moisture value, without limitation.

The method may further comprise the adaptive step of determining if one or more control set points within the one or more initialized control set points should be adjusted for a second filtration cycle (which is to occur after the first filtration cycle), based on the first target difference value, without limitation.

The method may further comprise the adaptive step of maintaining one or more of the initialized control set points of the first filtration cycle for the second filtration cycle, if the first target difference value falls within an acceptable range; or, reinitializing one or more of the initialized control set points of the first filtration cycle, for the second filtration cycle, if the first target difference value falls within an unacceptable range. It should be understood that in some cases, one or more control set points may be left unchanged between filtration cycles, and/or one or more control set points may change between filtration cycles, without limitation. Moreover, it should be understood that for any given new filtration cycle, one or more previously initialized control set points may change (i.e., be "re-initialized"), whereas one or more other previously-initialized control set points may not change, without limitation.

In some embodiments, the method may further comprise iteratively performing some or all of the aforementioned steps for at least a third filtration cycle. For example, in some embodiments, filter cake 60, 61 formed during the second filtration cycle may be analyzed to determine a second actual filter cake moisture value for filter cake 60, 61 produced by the filtration process during the second filtration cycle. The second actual filter cake moisture value may be compared

with the established target filter cake moisture value to determine a second target difference value therebetween.

5 The second target difference value may comprise the difference between the second actual filter cake moisture value and the established target filter cake moisture value, or, it may comprise the difference between the second actual filter cake moisture value and the first actual filter cake moisture value, without limitation. It may then be determined whether or not one or more control set points used for the second filtration cycle should be adjusted for a third filtration cycle (occurring after the second filtration cycle), based on the second target difference value.

15 In some embodiments, if the target difference value is acceptable (i.e., falls within an acceptable range), then one or more control set points of the second filtration cycle may be maintained for the third filtration cycle. Or, if the target difference value is unacceptable (i.e., falls within an unacceptable range), then one or more control set points of the second filtration cycle may be "re-initialized" (i.e., changed, or adjusted) for the third filtration cycle, without limitation.

20 According to some embodiments, the method may further comprise the step of measuring one or more feed process variables selected from the group consisting of: a mineralogy of the slurry 20, a particle size distribution of the slurry 20, and a density of the slurry 20. This measured data (from the measured one or more feed process variables) may be used to determine if one or more control set points should be adjusted, without limitation.

30 According to some embodiments, one or more of the abovementioned steps of analyzing, comparing, determining, and maintaining may be carried out autonomously, for example, by executing an operating algorithm 10 configured for receiving a number of inputs 11, and delivering a number of outputs 12, based on the inputs 11. In some cases, the inputs 11 may include, without

limitation, meteorological data selected from one or more of the group consisting of: current relative % humidity, forecasted relative % humidity, current % chance of precipitation, forecasted % chance of precipitation, current temperature, forecasted temperature(s), current percent sky cover, forecasted percent sky
5 cover, current UV index, forecasted UV index, current type of precipitation falling, type of precipitation (e.g., snow, rain, sleet, hail, wintry mix, freezing fog) forecasted, current wind speed(s), forecasted wind speed(s), current wind direction(s), forecasted wind direction(s), current precipitation totals, and forecasted total amounts of accumulated precipitation over a specified duration of
10 time into the future. An outputs 12 may include an instruction for controlling the belt speed of a conveyor 7, 8 moving filter cake 60, 61 produced by the filtration process.

In this regard, if the local weather is conducive to drying filter cake 60, then
15 control set points pertaining to filtration parameters may be adjusted to more efficiently produce a fresh filter cake 60 having a higher moisture content – wherein final drying may be performed on the conveyor 7, 8 (i.e., during conveying) to produce a final filter cake 61 meeting or exceeding the established target filter cake moisture value, without limitation. Alternatively, if the local
20 weather is conducive to increasing the moisture of a filter cake 60, then control set points pertaining to filtration parameters may be adjusted to less-efficiently produce a drier filter cake 60 leaving a filter 5, the filter cake 60 having a lower moisture content – wherein even after environmental exposure to water (e.g., humidity, rain, sleet, snow) while being moved on the conveyor 7, 8, the final filter
25 cake 61 may meet or exceed the established target filter cake moisture value, without limitation.

In some embodiments, the method may comprise the steps of: measuring an
upstream actual filter cake moisture value for filter cake 60 formed by the filter 5
30 with an upstream moisture analyzer 25; measuring a downstream actual filter cake moisture value for filter cake 61 conveyed by a conveyor 7, 8 for a period of

time and exposed to environmental elements for that same period of time; and, autonomously changing a belt speed of the conveyor 7,8, if there is a difference between the upstream and downstream actual filter cake moisture values which falls outside of an acceptable range, without limitation.

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A filtration system 1 for use in a filtration process is further disclosed. According to some embodiments, the filtration system 1 may comprise: a filter 5; a control system 80 for controlling the filter 5; a target filter cake moisture value for filter cake 60, 61 to be produced by the filtration process; and a pump 3 for feeding
10 slurry 20 to the filter 5, without limitation. The filtration system 1 may further comprise one or more control set points, the one or more control set points pertaining to filtration parameters selected from the group consisting of: feed slurry flow rate, feed slurry temperature, feed slurry pressure, feed slurry fill time, feed slurry totalized flow (e.g., volume), cake air blow on/off Boolean logic value,
15 cake air blow pressure, cake air blow time, membrane squeeze on/off Boolean logic value, membrane plate inflation pressure, membrane plate inflation time. The filtration system 1 may further comprise a control set point pertaining to conveyor 7, 8 belt speed, without limitation. The filtration system 1 may be characterized in that it further comprises one or more moisture analyzers 25, 26
20 for measuring an actual filter cake moisture value for filter cake 60, 61 formed during a filtration cycle and an executable operating algorithm 10.

The executable operating algorithm 10 may be configured for comparing the actual filter cake moisture value with a target filter cake moisture value, without
25 limitation. The executable operating algorithm 10 may also be configured for determining if one or more control set points used during the filtration cycle should be adjusted for a subsequent filtration cycle (e.g., to ensure that the actual filter cake moisture value meets or exceeds the target filter cake moisture value), without limitation. The executable operating algorithm 10 may further be
30 configured for providing instructions to adjust one or more control set points, as necessary, to ensure that the actual filter cake moisture value of the produced

filter cake 60, 61 meets or exceeds the target filter cake moisture value, without limitation. In operation, the executable operating algorithm 10 may be configured to change at least one control set point within the one or more initialized control set points, for example, if the difference between the upstream and downstream
5 actual filter cake moisture values is significant, without limitation.

In some embodiments, the filtration system 1 may comprise an x-ray diffraction (XRD) analyzer 21, a particle size distribution (PSD) analyzer 22, a density meter 34, a temperature analyzer 35, a weather analyzer 31, a feed slurry pressure
10 transducer, an in-pit sampling device 30, or any combination thereof, without limitation, in order to gather inputs 11 which may be used to determine whether to maintain or change certain control set points which affect operations within the filtration system. In some embodiments, the filtration system 1 may comprise an upstream moisture analyzer 25 for measuring an upstream actual filter cake
15 moisture value for filter cake 60 formed by the filter 5. In some embodiments the filtration system 1 may comprise a downstream moisture analyzer 26 for measuring a downstream actual filter cake moisture value for filter cake 61 conveyed by a conveyor 7, 8 for a period of time and exposed to environmental elements for that same period of time. In operation, the executable algorithm 10
20 may be configured to autonomously change a belt speed of the conveyor 7, 8, (e.g., by delivering an instruction to a control system 80 of the filtration system 1), if there is a difference between the upstream and downstream actual filter cake moisture values which is unacceptable (i.e., falls outside of an acceptable range).

25 The executable operating algorithm 10 may be configured to receive a number of inputs 11, and deliver a number of outputs 12, based on the inputs 11. For example, the inputs 11 may include, without limitation, meteorological data selected from one or more of the group consisting of: current relative % humidity, forecasted relative % humidity, current % chance of precipitation, forecasted %
30 chance of precipitation, current temperature, forecasted temperature(s), current percent sky cover, forecasted percent sky cover, current UV index, forecasted

UV index, current type of precipitation falling, type of precipitation (e.g., snow, rain, sleet, hail, wintry mix, freezing fog) forecasted, current wind speed(s), forecasted wind speed(s), current wind direction(s), forecasted wind direction(s), current precipitation totals, and forecasted total amounts of accumulated
5 precipitation over a specified duration of time into the future. The outputs (12) may include, without limitation, an instruction for controlling the belt speed of a conveyor 7, 8 moving filter cake 60, 61 produced by the filtration process.

BRIEF SUMMARY OF THE DRAWINGS

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To complement the description which is being made, and for the purpose of aiding to better understand the features of the invention, a set of drawings illustrating new and novel methods and apparatus for improving industrial filtration processes is attached to the present specification as an integral part
15 thereof, in which the following has been depicted with an illustrative and non-limiting character. It should be understood that like reference numbers used in the drawings (if any are used) may identify like components.

FIG. 1 illustrates a novel and inventive filtration system according to some
20 exemplary, non-limiting embodiments.

FIGS. 2 and 3 illustrate method steps which may be practiced according to some exemplary, non-limiting embodiments.

25 FIG. 4 illustrates how different sites with filtration system installations may connect with each other and/or with third party sites which may or may not have a filter 5, in order to share data, assist adaptive learning of operating algorithms, and/or to improve operating algorithms, without limitation.

30 FIG. 5 illustrates an exemplary, non-limiting embodiment of a filter plate 5a, which may be utilized in a filter 5, such as a horizontal automatic filter press,

without limitation. As shown, the filter pate 5a may comprise one or more cake moisture analyzers 25, 26 and/or one or more respective data transmitters 39, 40 thereon.

- 5 FIG. 6 shows an example of a pressure filter 5 provided as a horizontal automatic filter press, which may practice the inventive concepts disclosed herein, without limitation.

FIG. 7 briefly illustrates how a horizontal automatic filter press works, according
10 to some non-limiting embodiments.

FIG. 8 suggests an exemplary process flow according to some non-limiting embodiments.

- 15 In the following, the invention will be described in more detail with reference to drawings in conjunction with exemplary embodiments.

DETAILED DESCRIPTION

- 20 While the present invention has been described herein using exemplary embodiments of a filtering device 5, filtration system 1, and method of operating the same, it should be understood that numerous variations and adaptations will be apparent to those of ordinary skill in the field from the teachings provided herein.

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The detailed embodiments shown and described in the text and figures should not be construed as limiting in scope; rather, all provided embodiments should be considered to be exemplary in nature. Accordingly, this invention is only limited by the appended claims.

30

The inventors have recognized a novel and heretofore unappreciated method of controlling a filtration process which involves the operation of a filtering device 5; for example, an automatic filter press, without limitation.

- 5 Embodiments of the method may involve the employment and use of certain instrumentation (e.g., a series of online sensors which are configured to independently measure different attributes of a filtration process throughout a filtration system 1) in combination with data analytics. The data analytics may be performed autonomously via an operating algorithm 10, without limitation.

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- The method preferably predicts properties of filter cake 60, 61 being produced by a filtration process or system 1. Predictions are based upon one or more received inputs 11 which may comprise measurements and related data procured by the instrumentation, and the operating algorithm 10 may use these
- 15 predictions to recommend one or more changes to control set points pertaining to filtration parameters of the filtration system 1 or filtration process. The operating algorithm 10, may, for example, provide an instruction to a controller 70 of a control system 80 within a filtration system 1, to adjust, change, or otherwise “re-initialize” one or more control set points pertaining to filtration parameters
- 20 selected from the group consisting of: feed slurry flow rate, feed slurry pressure, feed slurry fill time, cake air blow on/off Boolean logic value, cake air blow pressure, cake air blow time, membrane squeeze on/off Boolean logic value, membrane plate inflation pressure, membrane plate inflation time, and/or conveyor 7, 8 belt speed, without limitation. Changes to set points may be made
- 25 to ensure that filter cake products 60, 61 meet or exceed target expectations (e.g., with regard to cake moisture content or density, without limitation).

- In some embodiments, control set points may directly relate to operations of a filter 5. For example, a control set point such as the filtration cycle time may be
- 30 initialized or re-initialized before a filtration cycle to maximize filtration process efficiency. Since longer filtration cycle times can reduce throughput and/or

reduce overall filtration process efficiency, the operating algorithm 10 may be advantageously configured to minimize filtration cycle time, based on one or more feed process variables (e.g., mineralogy, particle size distribution, and/or density of incoming slurry 20 being fed to a filter 5). The operating algorithm 10
5 may also be advantageously configured to minimize filtration cycle time, based on one or more product variables (e.g., cake moisture and/or cake density being achieved by a filter 5). For example, the operating algorithm 10 may be configured such that when cake product 60 being produced is much drier than it needs to be (i.e., has a moisture content which more than exceeds a target cake
10 moisture value), the operating algorithm provides an instruction or command to a controller 70 to reduce a filtration cycle time control set point for the next/subsequent filtration cycle. The filtration cycle time control set point may be iteratively reduced, in increments, over a number of successive filtration cycles, until the filter cake 60 being produced by the filter 5 approaches the target
15 specification for moisture content. In this regard, filtration cycle time may be reduced to only the amount of time needed to meet or exceed a target cake moisture specification.

It should be understood that a desired cake product having a target cake
20 moisture and/or density may be specified as a target specification for a particular process, and that target specifications may change over time with dynamic processes, or, may differ for dissimilar processes, without limitation.

As another example, a control set point such as whether or not to employ an air
25 blow cycle or a membrane squeeze step may be initialized or re-initialized before a filtration cycle to maximize filtration process efficiency. Since these additional filtration steps extend a filtration cycle and require energy, they can reduce throughput and/or overall filtration process efficiency. Accordingly, the operating algorithm 10 may be advantageously configured to maximize filtration process
30 efficiency by only requiring an air blow cycle and/or a membrane squeeze step during a filtration cycle, if necessary, based on one or more feed process

variables (e.g., mineralogy, particle size distribution, and/or density of incoming slurry 20 being fed to a filter 5) and/or one or more product variables (e.g., cake moisture and/or cake density being achieved by a filter 5) being delivered as inputs 11 to the operating algorithm 10. For example, before a given filtration cycle, the operating algorithm 10 may determine that based on inputs 11 such as the mineralogy of slurry 20 entering a filter 5, the particle size distribution of the slurry 20 entering the filter 5, the density of the slurry 20 entering the filter 5, and/or the percent moisture content of filter cake 60 currently being produced by the filter 5, that an air blow cycle should be used in the next filtration cycle. Alternatively, before a given filtration cycle, the operating algorithm 10 may conversely determine that based on inputs 11 such as the mineralogy of slurry 20 entering a filter 5, the particle size distribution of the slurry 20 entering the filter 5, the density of the slurry 20 entering the filter 5, and/or the percent moisture content of filter cake 60 currently being produced by the filter 5, that an air blow cycle should not be used in the next filtration cycle, in order to increase efficiency of the filtration process.

Similarly, before a given filtration cycle, the operating algorithm 10 may determine that based on inputs 11 such as the mineralogy of slurry 20 entering a filter 5, the particle size distribution of the slurry 20 entering the filter 5, the density of the slurry 20 entering the filter 5, and/or the percent moisture content of filter cake 60 currently being produced by the filter 5, that a membrane squeeze step should be employed in the next filtration cycle. Alternatively, before a given filtration cycle, the operating algorithm 10 may conversely determine that based on inputs 11 such as the mineralogy of slurry 20 entering a filter 5, the particle size distribution of the slurry 20 entering the filter 5, the density of the slurry 20 entering the filter 5, and/or the percent moisture content of filter cake 60 currently being produced by the filter 5, that membrane squeeze step should not be used in the next filtration cycle, in order to increase efficiency of the filtration process.

It should be understood that a duration of one or more filtering steps within a filtration cycle may be maintained or adjusted, according to inputs 11 and measured product variables, in order to achieve a specific desired filter product specification (e.g., having a particular filter cake moisture and/or density), or to
5 produce a homogenous or consistent filter cake 60, 61, over time, without limitation.

Turning to FIG. 1, a filtration system 1 according to some embodiments of the invention is shown. While the figure depicts many numbered elements, the
10 filtration system 1 shown may comprise only some or all of the numbered elements depicted in the figure, in any desired combination, and it should be understood by those ordinarily skilled in the art that any number of permutations or derivatives from what is shown is anticipated. For example, the filtration system 1 may omit one or some of the numbered elements as a matter of
15 preference or engineering design choice, in order to simplify the filtration system 1 from what is shown. Accordingly, numbered elements pertain to certain technical features with respective technical effects and benefits and it should be understood that some of these technical features may intentionally not be practiced or may be omitted without departing from the scope.

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Filtration systems 1 described herein comprise a filter 5 being controlled by a control system 80 provided with a controller 70. The controller 70 and filter 5 are operatively integrated with a control algorithm 10 and are preferably integrated with "the cloud" 2 for convenient data storage and analytics. Integration with the
25 cloud 2 may be accomplished, for example, with a data network 2a (e.g., a server farm/cluster, the Internet, LAN, WAN, data communications network, VPN, cellular network, fiber optic network, PSTN, satellite network, a combination thereof, etc.).

30 In this regard, cloud computing protocols may be established for one or more sites 91, 92 having a filtration system 1, as well as one or more sites 90

configured for running, supporting, maintaining, observing, or controlling those sites 91, 92 having a filtration system 1. For example, as suggested in FIG. 4, a first site 91 of operation conducting a filtration process (e.g., comprising a filter 5 or filtration system 1) and a second site 92 of operation conducting a filtration process (e.g., comprising a second filter 5 or filtration system 1) may each be connected, via the web, to a control site 90 configured for running, supporting, maintaining, observing, or controlling filtration systems 1 or filters 5. The first 91, second 92, and control 90 sites may comprise a shared user or entity, or may comprise different users or entities, without limitation. Moreover, the first 91, second 92, and control 90 sites may comprise a shared site with a similar geographical location, or they may comprise different remote or distant geographical locations, without limitation.

In some instances, the control site 90 may comprise the manufacturer 90 of a filtration system 1 or of one or more filters 5 of a filtration system 1 provided to a site 91, 92, without limitation. In some instances, the control site 90 may comprise a third party entity, contractor, service provider, or the like, without limitation. The control site 90 may casually observe operations from the first 91 and/or second site 92, may record data obtained during filtration operations occurring at the first and/or second site 92, or may intervene in the operation of one or more filters 5 at a site 91, 92 by performing one or more of the following tasks alone or in any combination: providing one or more instructions to a controller 70 on the site 91, 92, providing one or more over-ride control inputs 11, remotely changing one or more control set points for a filter 5, delivering online software packages which are configured to install, update, or make necessary changes to an existing operating algorithm 10 which is local to a controller 70 of a site 91, 92, making one or more changes to inputs 11 and/or outputs 12 of an operating algorithm 10 in real-time, or the like, without limitation. Tasks performed by the control site 90 may be based upon received data uploaded to the cloud 2 by a site 91, 92 and accessed independently by the control site 90, without limitation.

One or more electronic documents 2b (e.g., drawing, spreadsheet, operating manual, etc.), one or more databases 2c (e.g., SQL database, data array, data matrix, etc.), and/or one or more program files 2d (e.g., operating algorithm 10, executable, client program, etc.) may be accessed, altered, uploaded, or downloaded by sites 90, 91, 92 according to electronic user access privileges or user agreements, without limitation. Access to the cloud 2 may be done through the employment and use of a user interface (e.g., GUI) provided to the controller 70 or other portion of the control system 80, without limitation.

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As shown, a pump 3 may be used to convey incoming feed slurry 20 to a filter 5 within the filtration system 1. The filter 5 may comprise, for example, a filter press, without limitation. On its way to the filter 5, an infeed conduit, pipe, or other conveying means may be provided with one or more of the following components, in order to collect and obtain data pertaining to the incoming feed slurry 20: an X-ray diffraction (XRD) mineralogy analyzer/analysis component 21, a particle size analyzer/analysis component 22, a density meter data transmitter/transmission component 34, a temperature data transmitter/transmission component 35, and a flow and/or pressure data transmitter/transmission component 36, without limitation. The collected data pertaining to the feed slurry 20 may be delivered to the controller 70 and used as one or more inputs 11 to an operating algorithm 10 for processing. The collected infeed slurry 20 data may also be uploaded or live streamed to a database 2c via the cloud 2.

If or when provided or used, the XRD mineralogy analyzer/analysis component 21 may include an XRD mineralogy data transmitter 32 which enables a transmission step of data pertaining to the composition, structure, and/or makeup of the incoming feed slurry 20 to the controller 70 of the filtration system 1. The XRD/mineralogy data may be regarded as an input 11 to an operating algorithm 10 associated with the controller 70, which is part of a larger control system 80 of the filtration system 1. The controller 70 may iteratively access and execute the

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operating algorithm 10, and use outputs 12 provided therefrom, to coordinate filter 5 control by adjusting or maintaining one or more initialized control set points for controlling and operating the filter 5 (or a plurality of filters), without limitation. For example, the mineralogy data pertaining to the incoming feed
5 slurry 20 may be used to initialize, set, or adjust/re-initialize one or more control set points for a filtration cycle within a filtration process to maintain good performance and/or efficiency. As shifts or changes in mineralogy occur, feed slurry fill time, feed slurry fill pressure, air blow time, air blow pressure, membrane squeeze cycle time, and/or membrane plate squeeze pressure may
10 change, per the operating algorithm 10.

The controller 70 may utilize one or more outputs 12 gathered from the executed operating algorithm 10 to relay instructions to one or more components within the filtration system 1, without limitation. The instructions may include, without
15 limitation: turning certain filtration steps (e.g., air blow cycle, membrane squeeze cycle) within a filtration cycle on or off; increasing or decreasing a component's operation speed (e.g., RPM of a pump 3 or belt speed of a conveyor 7, 8); increasing or decreasing a component's pressure setting (e.g., slurry feed pressure, air blow pressure, membrane plate inflation pressure, etc.); increasing
20 or decreasing the duration of a functional or operational step (e.g., filtration cycle time air blow cycle time, membrane squeeze cycle time, filter cake transit time, or the like), etc.

If or when provided or used in a filtration process, the particle size
25 analyzer/analysis component 22 may include a particle size distribution (PSD) data transmitter 33 which enables the transmission of data associated with the size of solids found in the incoming feed slurry 20. The particle size data may be relayed to a controller 70 within the filtration system 1, and provided as an input 11 to the operating algorithm 10, without limitation. For example, the particle size
30 data pertaining to the incoming feed slurry 20 may be used to initialize, set, or

adjust/re-initialize one or more control set points for a filtration cycle within a filtration process to maintain good performance and/or efficiency.

If or when provided or used in a filtration process, the density meter data transmitter/transmission component 34 may include data regarding the density of the incoming feed slurry 20. This density data may serve as an input 11 to an operating algorithm 10 for controlling a filter 5 (or a plurality thereof), without limitation. For example, the density data pertaining to the incoming feed slurry 20 may be used to initialize, set, or adjust/re-initialize one or more control set points for a filtration cycle within a filtration process to maintain good performance and/or efficiency. In some embodiments, density measuring equipment may include an online ultrasonic nuclear densitometer, nuclear density meter, or non-nuclear ultrasonic density meter (e.g., Rhosonics brand Model 9690 or SDM), without limitation.

If or when provided or used in a filtration process, the temperature data transmitter/transmission component 35 may include data regarding the temperature of the incoming feed slurry 20. This temperature data may serve as an input 11 to an operating algorithm 10 for controlling a filter 5 (or a plurality thereof), without limitation. For example, the temperature data pertaining to the incoming feed slurry 20 may be processed by the operating algorithm 10 to enable the controller 70 to initialize, set, or adjust/re-initialize one or more control set points for a filtration cycle within a filtration process to maintain good performance and/or efficiency. For example, if the incoming feed slurry 20 has a high enough temperature, a filter 5 may be able to reduce a filtration cycle time or skip a step within a filtration cycle due to a higher drying heat energy and possible reduction in filtrate liquor viscosity. In some non-limiting embodiments, air blow time may adjusted as a function of feed slurry temperature and may be reduced in duration for hotter incoming feed slurry temperatures, without limitation.

If or when provided or used in a filtration process, the flow and/or pressure data transmitter/transmission component 36 may include data regarding the flow rate of the incoming feed slurry 20, and/or the pressure of the incoming feed slurry 20. This pressure and/or flow data may also serve as an input 11 to an operating
5 algorithm 10 for controlling a filter 5 (or a plurality thereof), without limitation. As shown, the flow and/or pressure data transmitter/transmission component 36 may be operatively coupled to, or serve as an extension of the pump 3. For example, the pressure data pertaining to the incoming feed slurry 20 may be processed by the operating algorithm 10 to enable controller 70 to initialize, set,
10 or adjust/re-initialize one or more control set points for a filtration cycle within a filtration process to maintain good performance and/or efficiency. In some embodiments, the controller 70 may initialize, set, or adjust/re-initialize the pump's 3 operation speed control set point, without limitation. While flow and pressure is shown in the figures as being part of the same component, they are
15 separable and may be independently provided and/or spaced apart from one another, without limitation.

While not explicitly shown in the figures for clarity, in addition to XRD mineralogy data, particle size distribution data, density data, temperature data, flow data,
20 and/or pressure data, the pH of the incoming feed slurry 20 may be recorded using a pH analyzer and data transmitter and provided to an operating algorithm as an input 11. Still other inputs 11 for operating algorithm 10 are anticipated and may include analyzers and respective data transmitters which measure and relay data pertaining to things like abrasiveness of incoming feed slurry 20, clay
25 content of incoming feed slurry 20, moisture content of the incoming feed slurry 20 (e.g., via an upstream moisture analyzing sensor or probe), a combination thereof, or the like, without limitation.

Moreover, as suggested in FIG. 1, a weather analyzer 23 or meteorological analysis component (e.g., a weather station or local forecasting device) may be
30 provided as part of the filtration system 1 and may be employed to determine belt

speeds of filter cake 60, 61 conveyors 7, 8 and/or other set points for controlling a filtration process.

Moreover, as suggested in FIG. 1, a mine pit 24 (for ore extraction) may be provided as a component of a filtration system 1, according to some embodiments, without limitation; wherein in-pit mine sampling information may be obtained and delivered to the controller 70 as an input 11 to the operating algorithm 10, and then processed. The in-pit sampling information may comprise, without limitation, minerology data which may be used to adjust feed slurry filling time, air blow time, air blow pressure, and/or other input control set points or process variables.

If or when provided or used in a filtration process, the weather analyzer 23 may be operably-connected to the filtration system 1 via a weather data transmitter 31 which is configured to transmit meteorological data to the controller 70 as an input 11 to the operating algorithm 10 for controlling a filter 5 (or a plurality thereof), without limitation. The meteorological data may be processed and interpreted by the operating algorithm 10 to help the controller 70 adjust control set points pertaining to filtration parameters of a filter 5 and/or cake conveyor 7, 8 belt speeds, without limitation. Adjustments are preferably made so as to produce a fresh filter cake 60 product that meets or exceeds target moisture content and/or density specifications. However, more importantly, adjustments are preferably made so as to produce a final filter cake product 61 that also meets or exceeds target moisture content and/or density specifications - even after the initially-produced cake product 60 is exposed to environmental elements (i.e., outside weather/external atmosphere) for a duration of time while being moved or conveyed via one or more conveyors 7, 8 (e.g., an upstream conveyor 7 and/or a downstream conveyor 8), without limitation. Exposure to the elements may include, for instance, exposure to a forecasted amount of: rain, fog, sleet, snow, sun, wind, humidity, temperature, UV index, or the like, without limitation.

Hypothetically, if a weather analyzer 23 predicts 1 inch of rain spread evenly over a 24 hour timeframe, and conveyors 7, 8 within a filtration system 1 are uncovered and located outside of any buildings or structures and have an expected travel residence time of 12 hours, the operating algorithm 10 may use the transmitted 31 weather data to calculate, predict, or determine how much rainwater is likely to combine with freshly-discharged filter cake 60 during cake conveying (e.g., approximately $\frac{1}{2}$ inch of total rain over 12 hours, for a steady rain forecast). The operating algorithm may also calculate, predict, or determine what the approximate final cake 61 moisture content (wt% or vol%) might be after exposure to the rainwater over the conveying period. Thereafter, the operating algorithm 10 may optionally adjust one or more outputs 12 accordingly, based upon these aforementioned meteorological data inputs 11 and/or expected final moisture content for the final cake 61. The outputs 12 may be suggestions or instructions which are processed and used by the controller 70 to control a filter 5 and/or other devices or components 3, 4, 51 within the filtration system 1 for improved performance and efficiency of a filtration process.

As an output 12, the operating algorithm 10 may provide one or more instructions pertaining to changes in control set points to the controller 70 for execution. The controller 70, in turn, may execute those instructions and/or recommended run settings. In the above hypothetical case a filtration system 1 would be ideally configured with control set points that are initialized with values, which are capable of producing fresh filter cake 60 leaving a filter 5 that is dry enough to still meet or exceed target cake moisture and/or density specifications for the filtration process even after absorbing $\frac{1}{2}$ inch of expected rain during the 12-hour expected conveying period for conveyors 7, 8. This may be accomplished by maintaining or adjusting one or more previously initialized control set points for filtration system components 3, 4, 5, 7, 8, 51, and basing those decisions on various combinations of current process input 11 data, results data associated with product variables of the filter cake 60, 61 currently being produced, historical

process data inputs 11, and historical results data associated with product variables of filter cake 60, 61 produced in the past, without limitation.

Alternatively, if the weather analyzer 23 predicts sunny skies, high wind, little cloud cover, and/or a high UV index over the next 8 hours' time, and conveyors 7, 8 within the filtration system 1 are uncovered and have an expected cake travel residence time of 4 hours, then the operating algorithm 10 may calculate, predict, or determine how much liquid within a freshly-produced cake 60 might evaporate due to exposure to the elements while in transit on conveyors 7, 8 -- based upon these meteorological input 11 data, known historical average process conditions data, and past results/performance data associated with the known historical average process conditions data. In the aforementioned hypothetical example, the algorithm 10 may determine that highly evaporative conditions exist and that filtration parameter set points may be selected such that a wetter filter cake 60 (not yet meeting or exceeding target cake moisture value) is initially produced by a filter 5, but that the filter cake 60 will eventually reach its target dryness by the time it is conveyed for 4 hours and becomes a final filter cake 61, without limitation.

Alternatively, in the aforementioned hypothetical example, the algorithm may send an instruction to the controller 70 to decrease the belt speed of a conveyor 7, 8 in the filtration system 1, as a means to maximize exposure time to highly evaporative conditions. In this regard, the algorithm may conversely send an instruction to the controller 70 to increase the belt speed of a conveyor 7, 8 in the filtration system 1, as a means to minimize exposure time to highly wet environmental conditions. By synergistically using meteorological data and local environmental conditions, filtration process efficiency can be improved.

In some embodiments, conveyor time may only be a few minutes to an hour or so, and in such instances, conveyor speed control may be optionally held constant for simplicity, without limitation.

Calculations and approximations may be made by the operating algorithm 10 as to what a final cake 61 moisture content can be expected to be, and this value can be compared to a desired target cake moisture value previously established for the filtration process. The operating algorithm 10 may process the above information simultaneously, or in piecemeal to ultimately determine if adjustment to one or more real-time outputs 12 should be made. Outputs 12 could include, for example, and without limitation: a recommendation favoring re-initialization of one or more filtration process control set points within the filtration system 1 being made to the controller 70; a recommendation favoring taking one or more actions to reduce or increase the amount of total dewatering being performed by the filter 5; a recommendation favoring taking one or more actions which could reduce the total amount of energy being consumed by the filter 5 for a given filtration cycle, or the like, without limitation. The spirit of the invention is to provide quality inputs 11 for the operating algorithm 10, improve the overall controllability and efficiency of a filtration process, provide quality loop-feedback inputs to and outputs from a controller 70 of a filtration process, and increase functionality through adaptive learning and real-time data analytics involving historical process conditions and past results associated therewith.

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The operating efficiency of a filter 5 or a filtration process utilizing a filter 5 may be improved by relying on ambient meteorological conditions (e.g., environmental considerations, weather patterns, climate, etc.), accumulated historical data (e.g., regarding the quality of filter cake 60, 61 produced during certain times of the year or during certain weather conditions), and various trends revealed through data analytics, to assist with dewatering efforts. Accordingly, total filtration cycle time may be shortened, the duration of an air blow step within a filtration cycle may be reduced, an air blow cycle may be eliminated altogether, the time spent on a membrane squeeze cycle within a filtration cycle may be reduced, and/or a membrane squeeze cycle may be eliminated altogether, depending on which

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data 31 gathered from weather analyzer 23 is processed by the operating algorithm 10, without limitation.

5 Preferably, outputs 12 of the operating algorithm 10 favor reducing filtration energy consumed wherever possible, and instead, capitalizing on external free energy sources (e.g., solar, wind, low relative % humidity, high altitude location, etc.) which can assist with dewatering a filter cake 60.

10 In some embodiments, belt speed control set points for conveyors 7, 8, may be adjusted as an output 12 of operating algorithm 10. The belt speed of conveyors 7, 8 may be changed according to differences in properties between freshly-produced filter cake 60 and filter cake 61 which has spent some time on the conveyors 7, 8, without limitation. For example, if a downstream cake moisture analyzer 26 indicates that an aged final filter cake 61 (having been exposed to
15 external environmental elements for a period of time) has a higher moisture content than freshly-discharged cake 60 (measured by an upstream cake moisture analyzer 25), then control set points within the filtration process may be adjusted to speed up the conveying process and reduce exposure of filter cake 60 to moisture. Alternatively, or in combination with increasing belt speed control
20 set points, control set points within a filtration process may be selected to produce a drier freshly-discharged filter cake 60 to compensate for wetter climates and exposure to moisture during downstream conveying of filter cake 60 (albeit at the expense of slightly higher energy consumption).

25 If or when operably-integrated with a filtration system 1, a mine pit 24 may comprise a pit sampling data transmitter 30 which is configured to transmit data pertaining to ore makeup and composition as an input 11 to an operating algorithm 10 for controlling a filter 5 (or a plurality thereof), without limitation. Data pertaining to mined ore (e.g., ore minerology, XRD data, clay analysis, etc.)
30 may be transmitted to the controller 70 and the operating algorithm 10 may calculate necessary adjustments, in advance of feed slurry entering a filter 5.

Data transmitter 30 may serve the further purpose of providing a more accurate representation of future feed slurry which will arrive at the filter 5. Future filtration cycles may be adjusted based on mineralogies from various portions of the pit 24, and when those mineralogies are expected to arrive at the filter 5, without
5 limitation.

Another input 11 to operating algorithm 10 may include cake moisture data collected from a cake moisture analyzer 25 and pertaining to fresh cake 60 formed by a filter 5 or leaving a filter 5 or tray 6 within the filtration system 1,
10 without limitation. The cake moisture data may be transmitted via a cake moisture transmitter component 39 provided to an upstream conveyor 7, without limitation.

Another input 11 to operating algorithm 10 may include downstream or final cake
15 61 moisture data collected from a cake moisture analyzer 26 and transmitted from a downstream conveyor 8 to the controller 70 (as an input 11 to the operating algorithm 10) via a cake moisture transmitter component 40, without limitation.

20 Another input 11 to operating algorithm 10 may include filtrate flow data regarding the amount of filtrate 27 leaving a filter 5. The filtrate flow data may be delivered as an input 11 to the operating algorithm 10 via a filtrate flow data transmitter 38 provided between the filter 5 and filtrate storage 9 (e.g., a filtrate tank or holding reservoir or the like), without limitation.

25 Moreover, an input 11 to operating algorithm 10 may include flow and/or pressure data regarding the amount of air 28 (or gas) entering a filter 5 during an air blow process, by virtue of a compressor 4 provided upstream of the filter 5. A flow controller 52 (e.g., a valve, controller, or the like) may be associated with the
30 compressor 4 in order to alter: the amount (e.g., volume and/or flow rate) of air or gas entering the filter 5, the temperature of air or gas entering the filter 5, the

pressure of air or gas entering the filter 5, the amount of time air or gas is permitted to enter the filter 5 during an air blow process, a combination thereof, or the like, without limitation. Depending on how the operating algorithm 10 interprets and processes the inputs 11, an air blow step may be adjusted, initiated, or stopped, in order to maintain filter cake 60, 61 homogeneity, and/or to ensure that produced filter cake 60, 61 meets or exceeds target moisture content or density specifications without unnecessarily using measures that reduce efficiency. The flow and/or pressure data obtained from compressor 4 and/or flow controller 52 may be delivered as an input 11 to an operating algorithm 10 via a flow and/or pressure data transmitter 37 provided between the compressor 4 and control system 80, without limitation.

Where used herein, the term “cake moisture analyzer” may, according to some embodiments, comprise a cake moisture detection meter, cake moisture detection probe, cake moisture measuring device, cake moisture detection sensor, or the like, without limitation.

Where used herein, the terms “filter,” “filtering machine,” “filtering device,” “filtration apparatus,” and the like, may be used interchangeably and, according to some embodiments, may comprise a pressure filter or vacuum filter, without limitation. While these terms may include, without limitation, disc filters, drum filters, pan filters, horizontal belt filters, or the like; the inventive aspects disclosed are especially advantageous for use with devices such as filter presses (e.g., horizontal automatic filter presses), without limitation.

Where use herein, the term “membrane plate” may be used synonymously with “diaphragm”, without limitation. Where used herein, the term “automatically” and “autonomously” may be used interchangeably, without limitation. Where used herein, the terms “set point,” “setting,” and the like may be used interchangeably, without limitation.

Where use herein, the term “air” may include any and all types of gasses including, but not limited to steam, nitrogen, CO₂, or the like, without limitation.

5 Where used herein, “big data analytics” may be given its plain meaning within the art. It may essentially include the process of examining large data sets containing a variety of data types, i.e. big data, to uncover hidden patterns, unknown correlations, process trends, customer preferences and other useful information pertinent to filtration operations, without limitation.

10 Where used herein, the terms “transmitter” or “transmission step” may comprise apparatus or steps incorporating wired, wireless, or hybrid solutions using any suitable data communications protocol (IETF, IEEE, ISO, etc.). For example, TCP/IP, OSI, IPX/SPX, SNA, UDP, ICMP, HTTP, POP, FTP, IMAP, and other protocols or may be employed by instrumentation disclosed herein, without
15 limitation.

Where used herein (including the claims), the term X-ray diffraction (XRD) may be replaced with equivalent or substantially-equivalent technologies for analyzing mineral composition and content. For example, XRD may be replaced with
20 technologies including, but not limited to Quantitative Evaluation of Minerals by Scanning Electron Microscopy, QEM scanning electron microscope, “QEM*SEM”, or equivalent, without limitation. Accordingly, the terms “XRD” and “QEM*SEM” may be used synonymously and/or interchangeably, without limitation. For example, one potential XRD equivalent may comprise a
25 QEMSCAN® integrated automated mineralogy and petrography solution comprising a Scanning Electron Microscope (SEM) with a large specimen chamber, up to four light-element Energy-dispersive X-ray spectroscopy (EDS) detectors, and proprietary software controlling automated data acquisition, without limitation.

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According to some embodiments, inputs 11 provided to operating algorithm 10 may include, without limitation, one or more of the following: feed slurry particle size and/or size distribution, feed slurry mineralogy (e.g., clay content), feed slurry flow rate, feed slurry totalized flow, feed slurry density, feed slurry temperature, feed slurry totalized flow (e.g., volume), feed slurry pressure, feed slurry pH, air blow "on/off" Boolean logic value, air blow air-flow rate, air blow air pressure, air blow duration, cake moisture (e.g., cake moisture on a belt of a conveyor 7 prior to exposure to elements, cake moisture on a belt of a conveyor 8 after exposure to elements, or cake moisture of cake 60 formed within filtration chamber of a filter plate 5a), weather information, membrane squeeze "on/off" Boolean logic value, membrane plate inflation pressure, membrane squeeze duration, or the like.

According to some embodiments, one or more outputs 12 from the operating algorithm 10 may include, without limitation: changes to the flow of incoming feed slurry 20 being delivered to a filter 5; changes in the pressure of incoming feed slurry 20 being delivered to a filter 5 (e.g., changes to the RPM, current/voltage, speed, or other operating condition of pump 3); changes to air blow usage (e.g., switching "on/off" Boolean logic value); changes to air flow rate to a filter 5; changes to air blow air pressure, changes to compressor 4 control set points; changes to one or more flow controller 52 set points; changes to membrane squeeze usage (e.g., switching "on/off" Boolean logic value); changes to membrane squeeze time for a filter 5; changes to conveyor 7, 8 belt speed set points, uploading and/or automatically storing recorded data to the cloud 2 or a local database 2c; generating one or more analysis reports (e.g., which may outline or communicate a filter's 5 past performance, current performance, analytics, trends, and/or predicted future performance, set points frequently changed, mean values used for each control set point, median values for each control set point, mode for each control set point, historical cake product characteristics observed over time, trends relating to how cake moisture may be

affected by certain input 11 changes (e.g., mineralogy), and/or a combination thereof, without limitation.

According to some embodiments, an output 12 of operating algorithm 10 may
5 comprise data being transmitted to and/or received from the cloud 2 via a data transmitter 50. The transmission of data to the cloud 2 may be unidirectional (e.g., upload or download only) or bi-directional (upload and download), without limitation. The transmission of data to the cloud 2 may be accomplished via
10 conventional software, hardware, networks, network components, or the like, without limitation.

In some embodiments, an output 12 of operating algorithm 10 may comprise an adjustment of a pressure controller 51 (e.g., air blow pressure controller or
15 membrane squeeze plate inflation pressure controller) which controls a fluid filling pressure of a membrane squeeze cycle. While air is preferred, the membrane squeeze cycle may utilize a liquid as the fill fluid, without limitation. The pressure controller 51 is configured to set a membrane plate inflation
pressure of one or more filter plates 5a within the filter 5, without limitation.

20 Moreover, in some embodiments, an output 12 of operating algorithm 10 may comprise an instruction being sent to a flow data controller 53, said instruction being used to adjust one or more control set points of the pump 3 to alter its current mode of operation. In other words, depending on inputs 11 received and processed, the operating algorithm 10 may determine that an appropriate output
25 12 instruction for the controller 70 to execute may be to slow down or speed up a pump 3 motor to decrease or increase, respectively, the feed slurry pressure for the filter 5, the feed slurry fill time, and/or the moisture content of a cake 60 produced by the filter 5, without limitation.

30 It should be understood that an operating algorithm 10 may be located locally (e.g. within a site 91, 92 controller 70), remotely (e.g., in the cloud 2), and/or at a

control site 90 remote from a site 91, 92 employing the predictive and/or adaptive filtration system 1 described herein, without limitation.

Exemplary, non-limiting methods 100, 200 according to some embodiments are shown and described in FIGS. 2 and 3, respectively. One or more inputs 11 may be introduced to an operating algorithm 10 associated with a controller 70. According to some embodiments, inputs 11 may include, for example: information regarding feed slurry 20 mineralogy, feed slurry 20 particle size information, feed slurry 20 flow data (e.g., flow rate, totalized volume, etc.), information pertaining to feed slurry 20 density, feed slurry 20 temperature data, feed slurry 20 pressure data, information regarding the pH of incoming feed slurry 20, air or gas flow information (e.g., flow rate, totalized volume, etc.), air or gas pressure data, cake moisture data (including upstream and downstream of a conveyor 7, 8, and inside or outside of a filtration chamber), weather/meteorological data, data regarding current conveyor belt speed(s), and a combination thereof, without limitation.

After processing one or more inputs 11 the operating algorithm 10 may produce one or more outputs 12 for manipulating components of a filtration process to achieve the best efficiency. The outputs 12 may assist controller 70 and greater control system 80 with maintaining or changing one or more filtration process control set points as needed to most efficiently meet or exceed target product variables (e.g., a target filter cake moisture value and/or target filter cake density value), without limitation.

According to some embodiments, outputs 12 may include, without limitation, changes to feed slurry 20 flow, changes to feed slurry pressure, changes to air/gas flow, changes to air/gas pressure, changes to use of an air blow cycle, changes to membrane squeeze time, changes to membrane squeeze pressure, changes to use of a membrane squeeze cycle, storing information in the cloud, accessing information from the cloud, and/or generating one or more reports.

Instrumentation may be used throughout a filtration system 1, to assist with data collection for the operating algorithm 10. Instrumentation may comprise, without limitation, online sensors, probes, flow analyzers/data transmitters, temperature
5 analyzers/data transmitters, pressure analyzers/data transmitters, flow controllers, pressure controllers, temperature controllers, slurry density meter/data transmitters, particle size distribution analyzers/data transmitters, mineralogy analyzers/data transmitters (e.g., analyzers which employ the use X-ray diffraction (XRD) techniques or other mineralogy determination
10 methodologies), cake moisture analyzers/data transmitters, cake density analyzers/data transmitters (not shown), filtrate flow analyzers/data transmitters, and/or the like, without limitation.

In some embodiments, one or more inputs 11 to operating algorithm 10 may be
15 calculated, rather than physically measured. For instance, cake density may be measured, rather than calculated, or vice-versa. As another example, feed slurry density may be calculated, rather than measured, or vice-versa. As another example, moisture content may be calculated, or vice-versa. In any number of
20 embodiments, an input 11 may be both measured and/or calculated, without limitation. By providing both measured and calculated values to the operating algorithm 10, redundancy is achieved and errors can be mitigated by interpreting both provided values.

For a given certain filtration cycle, one or more of the following steps may occur,
25 without limitation. One or more feed process variables, one or more filtration parameters, and one or more product variables such as cake moisture and/or cake density of produced filter cake 60, 61 may be measured. The respective data may be recorded and stored in a database 2c (e.g., in the cloud 2) for later accessing. For example, after a filtration cycle is completed, the cake moisture
30 and/or density of filter cake 60 produced by the completed filtration cycle may be

measured and compared with the respective data already recorded, uploaded, and/or stored for one or more earlier preceding filtration cycles.

Product variable values such as measured cake moisture and/or density, may
5 also be tagged, recorded, and uploaded to a database 2c for each filtration cycle, together with respective measured feed process variables and current filtration parameters for each filtration cycle, and stored in the database. It should be understood that any number or combination of process control inputs 11, filter 5 settings, and/or process control set points may be tagged, recorded, and
10 uploaded to a database 2c for each filtration cycle, without limitation.

Filtration parameters may correspond to one or more filter 5 settings or control set points for a particular measured filtration cycle. The filtration parameters may be recorded and/or monitored over time and stored in the database 2c for later
15 accessing, processing, and/or use (e.g., analytics). Data acquisition may take place at any time between filtration cycles, or during filtration cycles, and may also take place a plurality of times during a single filtration cycle, without limitation. For example, data acquisition may take place before each filtration cycle, after each filtration cycle, before and after each filtration cycle, at a point
20 during a filtration cycle, several times during a particular filtration cycle, over a predetermined number of filtration cycles, or sporadically or infrequently only after every few filtration cycles have passed, without limitation.

Subsequent filtration cycles may be measured in similar fashion. Preferably, a
25 filter 5 equipped with the inventive technology is configured to use "big data" analytics to test, fine-tune, and further develop one or more operating algorithms 10 used to control the filter 5, or, one or more aspects of a filtration process, such as initializing one or more control set points, without limitation. The information procured through the use of big data analytics may enable an operator of a filter
30 5 or filtration system 1 to preemptively determine the best combination of control set points (e.g., pertaining to feed process variables, filtration parameter

variables) for a given filtration process, based on given inputs 11 and historical data archived in a database 2c, in order to achieve desired or required product variables (e.g., i.e., target cake moisture and/or density).

- 5 Using big data analytics, filtration process control set points may be quickly and easily initialized using information stored in the cloud 2, and these big data analytics can take much of the guesswork out of commissioning new filtration processes. When coupled with real-time information continuously procured through filtration system 1 via instrumentation and online sensors taking
10 measurements during operation, historical data can be used to further improve and adjust algorithmic filters, better configure operating algorithms 10 for adaptive learning, and make high quality decisions within a filtration process.

15 EXAMPLE 1

A non-limiting exemplary method according to a particular embodiment of the invention follows.

- 20 In a first step of the exemplary method, one or more of the following feed process variables are measured: particle size distribution of a feed slurry entering into a horizontal automatic filter press, mineralogy of the incoming feed slurry, density of the incoming feed slurry, and the feed slurry flow rate (i.e., how much slurry by volume is entering the filter over time). The temperature of the incoming feed
25 slurry may be optionally measured as a feed process variable.

- Second, in addition to the above feed process variables being measured, one or more of the following filtration parameters (i.e., filter settings or control set points used during filter 5 operation) are measured in a second step: feed slurry
30 pressure, feed slurry fill time, cake air blow pressure, air blow time, membrane plate inflation pressure, and membrane plate inflation time.

In a third step, one or more of the following product variables are measured: cake moisture and/or cake density. In many instances, cake moisture may be considered to be a more important product variable than cake density, without
5 limitation. Accordingly, it may be preferred in most embodiments to measure at least cake moisture, without limitation.

Preferably, more than one variable from each of the three aforementioned steps is measured, in order to improve an operating algorithm over time.

10

For the first filtration cycle (i.e., cycle #1), preferably all of the aforementioned feed process variables and filtration parameters are measured during steps one and two.

15 After the first filtration cycle is completed, preferably both the product cake moisture and/or cake density are measured in the third step of the exemplary method.

For the next number of cycles (e.g., cycles #2 through cycle *N*), the horizontal
20 automatic filter press is operated the same as for the first cycle (cycle #1). However, the following additional step takes place. The product cake moisture is measured and is compared to the target cake moisture. Alternatively, or in addition to the product cake moisture, the product cake density is measured and compared to the target cake density.

25

The individual cycles are each tagged by storing all data for each filtration cycle in a database. The database is accessed by an operating algorithm, which accesses, processes, and/or utilizes data stored in the database to perform big data analytics thereon. Based on the resultant conclusions and data associated
30 with the analytics and operating algorithm, a processor within a controller determines how to change one or more of the filtration parameters and/or one or

- more of the feed process variables or filtration process set points. The processor may also determine how to change one or more of the filtration parameters, based upon one or more of the measured feed process parameters, in order to best achieve the target cake moisture and/or density. With each iterative cycle,
- 5 the operating algorithm and/or analytics tactics used may continually adapt and change. In other words, the method may involve "adaptive" learning techniques found in other industries and fields of endeavor (e.g., automotive, web-based advertising). The operating algorithm used by the processor may be self-learning.
- 10 For the next number of cycles (i.e., cycle no. $N+1$ and up), based upon the previous filtration cycle's measured cake moisture and/or density, the feed slurry fill time and/or the cake air blow time may be changed (or not), based upon the current feed process variables, in order to achieve the precise combination of variables that will produce a filter cake product closest to the target cake
- 15 moisture and/or density. The feed slurry pressure and/or the cake air blow pressure may be changed (or not), based upon the current feed process variables, in order to achieve the precise combination of variables that will produce a filter cake product closest to the target cake moisture and/or density. The cake air blow may be used or not used in a filtration cycle, based upon the
- 20 previous filtration cycle's measured cake moisture and/or density. This is an iterative process in which the data processor will preferably be configured to make real time decisions to best achieve the target product cake moisture and/or density, based upon historical actions taken and past results achieved.

25 EXAMPLE 2

While the above example is presented in reference to a horizontal automatic filter press, the heretofore-described process can also be practiced with a pressure filter or a vacuum filter alike, without limitation.

One major difference/adaptation for practicing embodiments of the invention with a vacuum filter (e.g., a horizontal belt filter), rather than with a pressure filter (e.g., filter press), is that an output 12 to the vacuum filter device might comprise adjustment of a belt speed of a filter belt – rather than involve the use of a
5 membrane squeeze, air blow, or feed slurry fill time.

In other words, for a horizontal belt filter 5, the belt speed of the filter 5 may be changed (i.e., slowed or sped up), based upon current feed process variables and their relation to the target cake moisture/density as well as historical data
10 regarding past feed process variables and cake moisture/density achieved using those variables.

15

EXAMPLE 3

In some embodiments, a filtration system 1 may be predictive-only (and may not comprise an adaptive response to changes to one or more measured inputs, in
20 order to arrive at a target cake moisture and/or density). In such “predictive-only” embodiments, the following steps may be employed, without limitation.

A fill process may commence, wherein feed slurry 20 enters a filter press 5 and fills filtration chambers between plates 5a within the filter press. During the fill
25 process for each filtration cycle, the average of each of the following inputs (i.e., feed process variables) may be accumulated and the data stored in memory: feed slurry density, feed particle size, feed pressure, feed flow (rate), feed mineralogy, and measured fill time.

30 Thereafter, an air blow process may commence, wherein air enters the filter press and helps dry cake forming in filtration chambers between plates within the

filter press. During the air blow process for each filtration cycle, the average of each of the following inputs (i.e., filtration parameters) may be accumulated and the data stored in memory: air/gas flow (e.g., flow rate), air/gas pressure, and measured air blow process time.

5

Thereafter, during the discharge portion of the filtration cycle the cake moisture may be determined, and an average cake moisture value may be recorded in memory.

10 In some embodiments, after the aforementioned steps have taken place, the following steps may then take place: virtually monitor the variation of input signals being measured or monitored; and, if there is erratic data, then determine that there is invalid data for a Kalman filter update.

15 Using averages obtained during the fill process (e.g., the average feed slurry density during the fill process, the average feed particle size during the fill process, the average feed pressure during the fill process, the average feed flow (rate) during the fill process, the average feed mineralogy during the fill process, and/or the average measured fill time during the fill process, without limitation),
20 use a Kalman filter (or linear quadratic estimation (LQE) algorithm) to calculate a predicted cake moisture value for the filter product.

Thereafter, adjust air flow and air pressure for an air blow process portion of the filtration cycle in order to achieve desired cake moisture.

25

Finally, compare the average cake moisture from the cake discharge portion of the filtration cycle to the predicted cake moisture value and adjust the Kalman filter to better predict cake moisture (as a function of said averages obtained during the fill process).

30

The variables, parameters, and process steps discussed herein and in the aforementioned examples are suggested in the appending figures.

In some embodiments, a filter press feed flow meter 36 may be used in combination with a slurry density meter 34 and the known volume of a filter 5, in order to determine or approximate the volume of feed slurry 20 that should be pumped into the filter 5. Such would be the case at any given slurry density of the incoming feed slurry 20. This same information may also be used to determine or approximate the preferred totalized volume of slurry 20 that should be pumped into the filter 5 to completely fill one or more filtering chambers within the filter 5 and also obtain a desired level of filter cake 60 consolidation, without limitation.

At least one cake moisture analyzer 25, 26 (e.g., a cake moisture detection meter, probe, measuring device, and/or analyzer) may be provided to one or more filtering chambers within a filter press 5. The cake moisture analyzer 25, 26 may be used to provide measured product cake moisture to the control system 80 during each filtration cycle, so that the control system (using a controller 70 provided with an operating algorithm 10 performing big data analytics) can determine which filter control set point values should be changed as output 12 variables. For instance, the control system 80 may, based upon the cake moisture information measured by the cake moisture analyzer 25, 26 automatically determine if an air blow or membrane squeeze step needs to be activated during a particular filtration cycle, in real-time, in order to achieve, meet, or exceed a desired target cake moisture for the cake product 60, 61.

If either or both of the cake air blow and membrane squeeze steps are required, the cake moisture analyzer 25, 26 may feedback cake moisture data to the PLC of controller 70 in real time via a transmitter 39, 40. The transmitter 39, 40 may be integral with or operate independently from the cake moisture analyzer 25, 26, without limitation. Once the cake moisture analyzer 25, 26 senses that the target

cake moisture has been achieved, or that an acceptable level of cake moisture has been reached (which is likely to or will produce an average cake moisture within target specifications), then the cake air blow and/or membrane squeeze may be stopped or used less frequently, in order to increase efficiency of the filter, reduce unnecessary energy inputs to the filter, and/or reduce filtration cycle time, without limitation.

In-situ onboard detection of cake moisture within the filter 5 (prior to discharging respective filter cakes from the filter 5) may be employed to enable the controller 70 of the filtration system to determine whether or not a given filtration cycle should perform a cake air blow and/or membrane squeeze (at one of a number of varying pressures), in real-time, to meet or exceed an established target cake moisture value. Detection of cake moisture within the filter 5 during cake formation may be accomplished with the provision and use of one or more moisture analyzers 25, 26 and/or transmitters 39, 40 provided to a filter plate 5a as suggested in FIG. 5. If moisture detection during cake formation and filtration cycle concludes that a cake air blow and/or a membrane squeeze process step is advised due to a measured cake moisture content which exceeds a predetermined cake moisture threshold (or is within an advisory range), the filtration system controller 70 may, according to operating algorithm output 12, adjust a particular filtration cycle independently of other filtration cycles, to insert said cake air blow and/or membrane squeeze process steps into said particular filtration cycle.

In other words, during a filtration cycle, moisture content of a formed cake 60 may be determined, and one or more control set point values may be changed based on the measured moisture content. The control set point values changed by the controller 70 may pertain to an "on/off" Boolean logic value for a cake air blow process, an "on/off" Boolean logic value for a membrane squeeze cycle, a duration of a cake air blow process (e.g. 0 seconds – 10 minutes in "n"-second

intervals), and a duration of a membrane squeeze cycle (e.g., 0 seconds – 10 minutes in “*n*”-second intervals), without limitation.

It should be understood that duration/time-based set point intervals may vary, and embodiments may use one-second, 5 second, 10 second, 30 second, 1-minute intervals, or other interval, without limitation. Duration/time-based set point resolution may even be less than one second, including fractions of a second, without limitation. For example, in some non-limiting hypothetical embodiments, a cake air blow process may be set to 20.35 seconds, without limitation,

It should also be understood that duration/time-based upper limit values of time set point range may vary, and that for certain embodiments those upper limit values may exceed the exemplary 10 minute maximum time used above. For example, a filtration process may be configured with time-based ranges from zero to 15 minutes or more, from zero to 30 minutes or more, from zero to 60 minutes or more, up to two hours (120 minutes) or more, or the like, without limitation.

In some embodiments, a number of cake air blow and/or membrane squeeze process steps may be inserted into a particular filtration cycle independently of other filtration cycles. In some embodiments, the controller 70 may, according to an operating algorithm 10, instruct the filter 5 to perform a number of successive filtration cycles – each incorporating a cake air blow and/or a membrane squeeze step, based upon past and/or recently-averaged feed process variables of an incoming feed slurry 20, without limitation. Performing one of the above steps may help ensure consistent and compliant filter cake products 60, 61, and may also help prevent problems commonly associated with conveying off-spec cake from under the filter 5 (e.g., having to isolate, handle, and determine the fate of the off-spec material after a filtration step has been completed).

Conversely, if detection concludes that a cake air blow and/or a membrane squeeze step is not advised for a filtration cycle due to in-situ measured cake moisture content already being within an acceptable cake moisture range after slurry fill, the filtration system's controller 70 may, according to an operating
5 algorithm, adjust control set points to skip or shorten said cake air blow and/or membrane squeeze process steps for that particular filtration cycle, in real-time, without limitation. Moreover, the filtration system's controller 70 may, according to an operating algorithm, instruct the filter 5 to skip one or both of the cake air blow and membrane squeeze steps for a given number of filtration cycles (e.g.,
10 for at least "N-number" of filtration cycles), based upon past and/or recently-averaged feed process variables of an incoming feed slurry 20, without limitation.

According to some embodiments, data procured from a cake moisture analyzer 25, 26 and stored in a database 2c may be used by the algorithm 10 and
15 controller 70 to automatically adjust a filtration feed pressure 36 control set point (e.g., by controlling one or more feed slurry pumps 3), without limitation.

For example, in a hypothetical situation where normal filtering typically occurs at 15 bar and produces filter cake comprising cake moisture levels which are lower than a minimum target cake moisture value, the operating algorithm 10, controller
20 70, and control system 80 may work in concert to iteratively reduce a filtration feed pressure 36 control set point, automatically, and in small increments, to a lower pressure level, until the desired target cake moisture value of a cake product 60, 61 is achieved. As another hypothetical example, where normal filtering might typically occur at 5 bar and produce a filter cake product having a
25 cake moisture level which exceeds a maximum target cake moisture, the operating algorithm 10, controller 70, and control system 80 may work in concert to iteratively increase the filtration feed pressure 36 control set point, automatically, and in small increments, to a higher pressure level, until the desired target cake moisture value of a cake product 60, 61 is achieved. This
30 technical feature and its respective technical effect may help reduce wear and tear on valves, pumps, and filter media found within filtration system 1, without

limitation. It should be understood that "in small increments" may comprise *equally*-small incremental changes, or, may comprise *unequally*-small incremental changes, for example, if using successive interval halving method, bisection method, binary search method, dichotomy method, or the like (see
5 related FIG. 8).

The inventive systems and methods disclosed herein may significantly improve upon the state-of-the art and currently-known methods of operating a filter 5, because they may take into consideration, the known volume of the filter
10 chambers of a filter press 5, and may use a density meter 34 to provide accurate data pertaining to the solids-to-liquid ratio being fed to the filter. Moreover, the disclosed systems and methods significantly improve upon the state-of-the art and currently-known methods of operating a filter 5, because a flow meter 36 (e.g., a wireless flow totalizer) may be used to provide real time totalized flow. In
15 this regard, real-time totalized flow can be used to calculate a feed slurry fill time which will provide a filter cake product 60, 61 having certain specifications.

In other words, with a measured incoming feed slurry 20 density of "x" (which may be known from density meter 34), a known predetermined chamber volume of "y", and a measured totalized incoming feed slurry flow of "z" (which may be known from flowmeter), it can be readily determined through simple calculation and/or processing, that the filter 5 will likely be completely filled to capacity when "z" equals or approaches a certain number. As density (x) and totalized flow (z) change over time (e.g., due to changing incoming feed slurry mineralogy,
25 changing particle size distributions, changing % solids, varying pumping motor current to a slurry feed pump 3, etc.), filtration parameters such as feed slurry pressure, feed slurry fill time, cake air blow pressure, cake air blow time, membrane plate inflation pressure, membrane plate inflation time, and/or cake discharge conveyor 7, 8 speed may be changed over time, according to a self-
30 learning, adaptive operating algorithm 10.

When used in a filtration system, a cake moisture analyzer 25, 26 may analyze a formed cake 60 and determine if a target cake moisture value requirement has been met or not. Depending on whether or not the cake moisture target value has been met or not, the operating algorithm 10 may instruct the controller 70 to
5 change the pressure control set point of the feed pump 3, without limitation.

EXAMPLE 5

As an example, and without limitation, a target cake moisture value for the
10 operating algorithm 10 may be established and set. If the target cake moisture value is hypothetically set with a particular threshold in mind (e.g., a target cake moisture content of 15% or less), and a first input 11 comprising measured feed pump pressure data 36 (e.g., 225 psi) yields a cake product 60 having a measured cake moisture of 13% (as measured by a first cake moisture detector
15 26), then the controller 70 of the control system 80 may, based on operating algorithm 10 outputs 12 and transmitted 39 moisture data, elect to change one or more inputs 11 (e.g., operational control set points) of the filter 5 for the next filtration cycle, so that the cake produced for the next filtration cycle is more likely to have a moisture content which is closer to 15% than 13%, and preferably
20 somewhere between 13% and 15%, but not over 15% moisture, in order to improve efficiency of the filtration process. Adjustment of the one or more inputs 11 may positively affect a composition 60 of filter cake produced by the filter 5, or may lead to corrective action of one or more inputs 11 or outputs 12 in iterative
fashion.

25

One or more changes to inputs 11 (such as changes to one or more control set points pertaining to filtration parameters), may involve the controller 70 of the control system 80 instructing the filter 5, based on algorithmic outputs 12, to be fed at a lesser feed slurry pressure (e.g., 200 psi) for the next filtration cycle than
30 an earlier or immediately-preceding filtration cycle. To accomplish this, one or more feed pumps 3 may be provided with less current, or, a control valve

provided between a feed pump 3 and the filter 5 may alternatively be adjusted to lower the feed pressure to the filter 5, without limitation. If downstream product measurements by one or more cake moisture analyzers 25, 26 determine that the cake moisture of the product 60, 61 has increased to an unacceptable, or
5 higher-than-required moisture content value (e.g., 16% moisture), then the operating controller 70 may elect to change one or more inputs 11 of the filter 5 for the next filtration cycle, based on outputs 12, such that the filter's 5 next filtration cycle feeds slurry 20 to the filter 5 at a slightly higher pressure (e.g., 215 psi) than the lesser feed slurry pressure. By increasing the pressure, efficiency
10 may be slightly reduced, and filter cake 60, 61 quality is achieved with (theoretically) the least (practical) amount of energy being used by the filtration process.

Similar decisions and instructions may be made by the operating algorithm 10
15 and controller 70, respectively, and this iterative loop-feedback process may repeat until the control system 80 hones in on a feed pump 3 pressure (or pressure range) which results in the most-efficient filter 5 control settings that are still able to produce a product which meets, exceeds, and/or maintains target cake moisture content over time.

20

Data recorded during the above process may be stored in a database 2c and used for big data analytics which keep the operating algorithm 10 updated.

A cake moisture analyzer 25, 26 described herein may, according to some
25 embodiments, determine if one or more subsequent filtration steps (e.g., such as membrane squeezing and/or a cake air-blowing process) should be conducted or not. The cake moisture analyzer 25, 26 may, in some embodiments, determine how long a filtration step within a filtration cycle should occur. In some embodiments, cake moisture analyzer data may be delivered to controller 70 via
30 one or more transmitters 39, 40 and used as inputs 11 to the operating algorithm 10 to determine which filtration process control set points should be used for one

or more subsequent filtration cycles, without limitation. If certain filtration steps are not required in a filtration cycle, based on currently-obtained cake moisture data 39, 40, then these discretionary functions may be skipped, thereby reducing cycle times, energy usage, providing higher throughput and capacity, and
5 minimizing operating costs and expenditures (OPEX).

In some embodiments, a retrofit kit comprising an operating algorithm 10 and accompanying software and/or hardware (e.g., instrumentation) may be provided to a filter 5, filtration system 1, or filtration process, in order to convert the same
10 to one which is predictive and/or adaptive in nature, and therefore configured to perform one or more of the "smart" functions or tasks described herein.

According to some non-limiting embodiments, the operating algorithm 10 may be configured to improve the operating efficiency of a filter 5, filtration process, or
15 filtration process, based upon inputs 11 received by the operating algorithm 10 (e.g., cake moisture data 39, 40 pertaining to the filter product 60, 61 produced by the filter 5).

In some embodiments, as suggested by FIG. 5, a first cake moisture data transmitter 39 may be provided to a filter plate 5a of a filter 5, rather than to a
20 conveyor 7 as shown in FIG. 1, and the first cake moisture data transmitter 39 may be located within a filter plate 5a or between filter plates 5a of the filter 5, without limitation. First cake moisture data transmission may therefore occur at or within a filter plate 5a of a filter 5, or between filter plates 5a of a filter 5, without limitation. Moreover, a second cake moisture data transmitter 40 may be
25 provided to a filter plate 5a of a filter 5, rather than to a conveyor 8 as shown in FIG. 1, and the second cake moisture data transmitter 40 may be located within a filter plate 5a or between filter plates 5a of the filter 5, without limitation. Second cake moisture data transmission may therefore occur at or within a filter plate 5a of a filter 5, or between filter plates 5a of a filter 5, without limitation. In
30 the particular non-limiting embodiment shown in FIG. 5, a first moisture analyzer 25 may record drier upper filter cake 60 portions, a first data transmitter 39 may

transmit the moisture data recorded by the first moisture analyzer, a second moisture analyzer 26 may record wetter lower filter cake 60 portions, and a second data transmitter 40 may transmit the moisture data recorded by the second moisture analyzer, without limitation.

5

This inventive technology may be applied to new or existing filtration device installations and may be rolled out to an existing global installed base. In some embodiments, different parties or entities may perform different steps or portions of steps which are used in the temporary decommissioning of, removal of parts
10 from, sizing of parts for, engineering of parts for, ordering of parts for, delivery of parts to, installation of parts, and/or recommissioning of, a filter device 5 or filtration system 1, without limitation. Moreover, multiple different parties or entities may collaborate or collectively execute different steps or portions of steps which are used in the aforementioned steps, without limitation.

15

The operating algorithm 10 described herein may be a unique local operating algorithm used and maintained locally at a particular site 91, 92, or, it may comprise a master operating algorithm which may be globally-shared and/or globally-accessed and merely accessed and/or used locally, without limitation. In
20 the latter case, a master operating algorithm may be updated by crowdsourcing data gathered from one or more sites 90, 91, 92, without limitation. The master operating algorithm may be proprietary in nature, without limitation.

The disclosure of every patent, patent application, and publication cited, listed,
25 named, or mentioned herein is hereby incorporated by reference in its entirety, for any and all purposes, as if fully set forth herein.

While this subject matter has been disclosed with reference to specific embodiments, it is apparent that other embodiments and variations can be
30 devised by others skilled in the art without departing from the true spirit and

scope of the subject matter described herein. The appended claims may include some, but not all of such embodiments and equivalent variations.

5 The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated and governed only by the appended claims, rather than by the foregoing description. All embodiments which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

10 A contractor or other entity may provide a filter as substantially described herein or may practice any one of the methods or method steps described herein, without limitation. Moreover, a contractor or other entity may provide portions or components of a filter as substantially described herein or may practice one or more of the method steps described herein, without limitation.

15

A contractor or other entity may provide a filter, filtration system, or component thereof. Or, a contractor or other entity may operate a filter or filtration system in whole, or in part, as shown and described.

20 A contractor or other entity may fabricate, provide, or install a filtration system as substantially shown and described herein, and this may include conversion of an existing filter to provide a predictive and/or adaptive filtration system. A contractor or other entity may receive a bid request for a project related to designing, fabricating, delivering, installing, operating, or performing maintenance on a predictive and/or adaptive filter or filtration system, or a component thereof as
25 substantially described herein, with the intention or purpose of converting an existing filtration operation to a “smart” adaptive filtration system described herein. Or, a contractor or other entity may offer to design such a system, device, or apparatus, or provide a process or service pertaining thereto, for a client. A contractor or other entity may offer to retrofit or may actually retrofit an existing
30 filter or filtration system with any one or more of the components described herein (e.g., control system, controller, operating algorithm, instrumentation,

analyzers, transmitters, or the like, without limitation), to make the existing filtration system “smart,” “predictive,” or “adaptive” in nature.

5 The contractor or other entity may provide, for example, any one or more of the inventive devices or features thereof shown and/or described in the embodiments discussed above in any combination, permutation, or fashion. The contractor or other entity may provide such devices or features by selling those devices or features; or, by offering to sell those devices or features. The contractor or other entity may provide various embodiments that are sized, shaped, specked, and/or
10 otherwise configured to meet the design criteria of a particular client or customer or end user of a filter or spare parts thereof.

The contractor or other entity may subcontract or facilitate the fabrication, delivery, sale, and/or installation of any component(s) of the system and
15 apparatus disclosed, or, of any component(s) of a device which might be used to reproduce inventive aspects of the embodiments disclosed (e.g., the novel instrumentation and operating algorithm, control system apparatus, and method steps for operating a filter and controlling a filtration process which are described herein). The contractor or other entity may also survey a site or design or
20 designate one or more storage areas for stacking material used to manufacture the devices used in the filtration system disclosed. Multiple contractors or other entities may work in concert together simultaneously or at different times, each party providing one or more of the inventive concepts, features, or novel method steps disclosed herein, or each party providing one or more components of the
25 novel filtration system disclosed herein.

The contractor or other entity may also maintain, modify, or upgrade a filter, a filtration system as described, or one or more components thereof. The contractor or other entity may provide such maintenance or modifications by
30 subcontracting such services or by directly providing those services or components needed for said maintenance, modifications, retrofit, or upgrades;

and, in some cases, the contractor or other entity may modify an existing filter or filtration system by virtue of provision of a “smart” or “predictive” or “adaptive” retrofit kit to arrive at a modified filter or filtration system comprising components described herein, or one or more of the inventive method steps, design features,
5 devices, or inventive concepts discussed herein.

Although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without departing from the
10 spirit of or exceeding the scope of the claimed invention.

REFERENCE NUMERAL IDENTIFIERS

- | | | |
|----|-----|---|
| | 1. | Filtration system |
| 5 | 2. | "Cloud" (e.g., the Internet, cloud computing, web-based storage protocol, etc., without limitation) |
| | 2a. | Network (e.g., server farm, data communications & computer network, local area network, wide area network, etc., without limitation) |
| 10 | 2b. | Electronic document (e.g., drawing, spreadsheet, operating procedures manual, instructions, without limitation) |
| | 2c. | Database (e.g., SQL, data array/matrix, etc., without limitation) |
| | 2d. | Program file (e.g., operation, executable, client program, script, etc., without limitation) |
| | 3. | Pump |
| 15 | 4. | Compressor (e.g., which may comprise a pump, tank, reservoir, gauge, or the like, without limitation) |
| | 5. | Filter (e.g. a pressure filter, a vacuum filter, a filter press, an automatic filter press, a horizontal filter press, a disk filter, a pan filter, etc., without limitation) |
| 20 | 5a. | Filter plate or plate assembly |
| | 6. | Tray |
| | 7. | Upstream conveyor |
| | 8. | Downstream conveyor |
| | 9. | Filtrate storage |
| 25 | 10. | Operating algorithm |
| | 11. | Input(s) (e.g., feed mineralogy, feed particle size distribution, feed flow rate, feed totalized flow, feed density, feed temperature, feed pressure, feed pH, air/gas flow rate, air/gas pressure, cake moisture (on belt of conveyor or in filtration chamber of filter 5), |
| 30 | | local weather/meteorological information, etc. without limitation) |

12. Output(s) (e.g., feed flow rate control, feed pressure control, cake air blow on/off Boolean logic value set, air/gas flow rate control, air/gas pressure control, membrane squeeze on/off Boolean logic value set, membrane squeeze time control, membrane plate inflation pressure control, digital export of data to storage, detailed report(s) generation, etc., without limitation)
20. Incoming feed slurry and/or filter feeding step
21. X-ray diffraction (XRD) mineralogy analyzer (or equivalent) and/or analysis step or the like (e.g., QEM*SEM Quantitative Evaluation of Minerals by Scanning Electron Microscopy techniques, QEM scanning electron microscope, or equivalent, may suffice as a substantially equivalent substitute, without limitation)
22. Particle size distribution (PSD) analyzer and/or analysis step
23. Weather analyzer and/or analysis step (e.g., weather station, local forecasting instrument, meteorological measuring equipment etc., without limitation)
24. Mine pit (e.g., exploration, mining facility, ore extraction operation, in-pit conveying, core sample database, etc., without limitation)
25. Cake moisture analyzer/analysis step (e.g., cake moisture detection meter, cake moisture detection probe, cake moisture measuring device, cake moisture detection sensor, on-line moisture sensor, etc., without limitation)
26. Cake moisture analyzer/analysis step (e.g., cake moisture detection meter, cake moisture detection probe, cake moisture measuring device, cake moisture detection sensor, on-line moisture sensor, etc., without limitation)
27. Filtrate
28. Gas (e.g., air, steam, nitrogen, CO₂, air for a cake "air blow" process, etc., without limitation)
30. Pit sampling data transmitter and/or pit sampling data transmission step (e.g., comprising pit mineralogy data)

31. Weather/meteorological data transmitter and/or weather/meteorological data transmission step
32. X-ray diffraction (XRD) mineralogy data transmitter and/or mineralogy data transmission step
- 5 33. Particle size distribution (PSD) data transmitter and/or particle size data transmission step
34. Density meter/measuring step, density analysis, and/or density data transmitter/transmission step
35. Temperature analyzer/analysis and/or temperature data transmitter/transmission step (e.g., thermocouple, digital thermometer, etc., without limitation)
- 10 36. Flow and/or pressure analyzer/analysis step and/or flow/pressure data transmitter/transmission step
37. Flow and/or pressure analyzer/analysis step and/or flow/pressure data transmitter/transmission step
- 15 38. Filtrate flow analyzer/analysis step and/or filtrate flow data transmitter/transmission step
39. Cake moisture (e.g., wt% or vol%) data transmitter and/or cake moisture data transmission step
- 20 40. Cake moisture (e.g., wt% or vol%) data transmitter and/or cake moisture data transmission step
50. Data transmitter and/or data communication step (e.g., software, hardware, network, data connection, data transmission, etc., without limitation)
- 25 51. Membrane plate inflation pressure controller and/or pressure control step with data transmission (not shown)
52. Flow controller and/or flow control step (e.g., based on output 12 data)
53. Flow meter and/or flow measurement step (e.g., based on output 12 data, a variable speed pump, etc.)
- 30

54. Data exchange (e.g., data uploads/downloads from sites (90, 91, 92), instruction uploads/downloads, operating algorithm updates, new versions of operating algorithms, remote monitoring client software upload/download, control software upload/download, software for installation at sites (90, 91, 92), data sent and received to/from cloud, etc., without limitation),
60. Filter cake (e.g., fresh from filter 5)
61. Filter cake (e.g., environment-exposed, aged, after being conveyed for a period of time)
70. Controller (e.g., CPU, processor with memory, hardware, software, PLC, etc., without limitation)
80. Control system (e.g., dashboard, graphical user interface (GUI), etc., without limitation)
90. Control site (e.g., manufacturer of filtration system or filter, third party servicing entity, monitoring entity, contractor, or the like, without limitation)
91. First site (e.g., user/entity, industrial filtration operations site, customer of filtration system 1 or filter 5, etc., without limitation)
92. Second site (e.g., user/entity, industrial filtration operations site, customer of filtration system 1 or filter 5, etc., without limitation)
100. Exemplary, non-limiting method
200. Exemplary, non-limiting method

CLAIMS

1. A method of controlling a filtration process utilizing a filter (5), the method comprising:
 - 5 establishing a target filter cake moisture value for filter cake (60, 61) to be produced by the filtration process;
feeding slurry (20) to the filter (5);
initializing one or more control set points for a first filtration cycle, the one or more control set points pertaining to filtration parameters selected from the
 - 10 group consisting of: feed slurry flow rate, feed slurry pressure, feed slurry fill time, feed slurry temperature, cake air blow on/off Boolean logic value, cake air blow pressure, cake air blow time, membrane squeeze on/off Boolean logic value, membrane plate inflation pressure, membrane plate inflation time, and conveyor (7, 8) belt speed;
 - 15 dewatering the slurry (20) with the filter (5) during the first filtration cycle;
forming a filter cake (60) with the filter (5) during the first filtration cycle;
and,
discharging the filter cake (60) from the filter (5) during the first filtration cycle;
 - 20 CHARACTERIZED IN THAT the method further comprises the adaptive steps of:
analyzing the filter cake (60) formed during the first filtration cycle to determine a first actual filter cake moisture value for filter cake (60, 61) produced during the first filtration cycle;
 - 25 comparing the first actual filter cake moisture value with the established target filter cake moisture value, to determine a first target difference value therebetween; the first target difference value comprising the difference between the first actual filter cake moisture value and the established target filter cake moisture value;

determining if one or more control set points within the one or more initialized control set points should be adjusted for a second filtration cycle occurring after the first filtration cycle, based on the first target difference value;

5 maintaining one or more of the initialized control set points of the first filtration cycle, for the second filtration cycle, if the first target difference value is within an acceptable range; or

reinitializing one or more of the initialized control set points of the first filtration cycle, for the second filtration cycle, if the first target difference value is within an unacceptable range.

10

2. The method according to claim 1, further comprising iteratively performing the described steps for at least a third filtration cycle; wherein the method comprises the steps of:

15 analyzing filter cake (60) formed during the second filtration cycle to determine a second actual filter cake moisture value for filter cake (60, 61) produced by the filtration process during the second filtration cycle;

20 comparing the second actual filter cake moisture value with the established target filter cake moisture value, to determine a second target difference value therebetween; the second target difference value comprising the difference between the second actual filter cake moisture value and the established target filter cake moisture value, or the difference between the second actual filter cake moisture value and the first actual filter cake moisture value;

25 determining if one or more control set points used for the second filtration cycle should be adjusted for a third filtration cycle occurring after the second filtration cycle, based on the second target difference value;

maintaining one or more control set points of the second filtration cycle, for the third filtration cycle, if the target difference value is within the acceptable range; or

reinitializing one or more control set points of the second filtration cycle, for the third filtration cycle, if the target difference value is within the unacceptable range.

- 5 3. The method according to any one of the preceding claims, further comprising:

measuring one or more feed process variables selected from the group consisting of: a mineralogy of the slurry (20), a particle size distribution of the slurry (20), and a density of the slurry (20); and

- 10 using data from the measured one or more feed process variables to determine if one or more control set points should be adjusted.

4. The method according to any one of the preceding claims, wherein one or more of the described steps of analyzing, comparing, determining, and
15 maintaining are carried out autonomously, by executing an operating algorithm (10) configured for receiving a number of inputs (11), and delivering a number of outputs (12), based on the inputs (11).

5. The method according to claim 4, wherein the inputs (11) include
20 meteorological data selected from one or more of the group consisting of: current relative % humidity, forecasted relative % humidity, current % chance of precipitation, forecasted % chance of precipitation, current temperature, forecasted temperature(s), current percent sky cover, forecasted percent sky cover, current UV index, forecasted UV index, current type of precipitation falling,
25 type of precipitation (e.g., snow, rain, sleet, hail, wintry mix, freezing fog) forecasted, current wind speed(s), forecasted wind speed(s), current wind direction(s), forecasted wind direction(s), current precipitation totals, and forecasted total amounts of accumulated precipitation over a specified duration of time into the future; and

wherein the outputs (12) include an instruction for controlling the belt speed of a conveyor (7, 8) moving filter cake (60, 61) produced by the filtration process.

- 5 6. The method according any one of the preceding claims, further comprising:

measuring an upstream actual filter cake moisture value for filter cake (60) formed by the filter (5) with an upstream moisture analyzer (25);

- 10 measuring a downstream actual filter cake moisture value for filter cake (61) conveyed by a conveyor (7, 8) for a period of time and exposed to environmental elements for that same period of time; and,

autonomously changing a belt speed of the conveyor (7,8), if there is a difference between the upstream and downstream actual filter cake moisture values which falls outside of an acceptable range.

15

7. A filtration system (1) for use in a filtration process, the filtration system (1) comprising:

a filter (5);

a control system (80) for controlling the filter (5);

- 20 a target filter cake moisture value for filter cake (60, 61) to be produced by the filtration process;

means (3) for feeding slurry (20) to the filter (5);

- one or more control set points, the one or more control set points pertaining to filtration parameters selected from the group consisting of: feed slurry flow rate, feed slurry pressure, feed slurry fill time, cake air blow on/off Boolean logic value, cake air blow pressure, cake air blow time, membrane squeeze on/off Boolean logic value, membrane plate inflation pressure, membrane plate inflation time, and conveyor (7, 8) belt speed;
- 25

- CHARACTERIZED IN THAT the filtration system (1) further comprises the following features:
- 30

one or more moisture analyzers (25, 26) for measuring an actual filter cake moisture value for filter cake (60, 61) formed during a filtration cycle; and an executable operating algorithm (10) configured for:

- i.) comparing the actual filter cake moisture value with the target filter cake moisture value,
- ii.) determining if one or more control set points used during the filtration cycle should be adjusted for a subsequent filtration cycle, to ensure that the actual filter cake moisture value meets or exceeds the target filter cake moisture value, and
- iii.) providing instructions to adjust one or more control set points, as necessary, to ensure that the actual filter cake moisture value of the produced filter cake (60, 61) meets or exceeds the target filter cake moisture value.

8. The filtration system (1) according to claim 7, further comprising one or more of the following components: an x-ray diffraction (XRD) analyzer (21), a particle size distribution (PSD) analyzer (22), a density meter (34), a temperature analyzer (35), a weather analyzer (31), and an in-pit sampling device (30).

9. The filtration system (1) according to claim 7 or 8, further comprising one or more of the following components: an upstream moisture analyzer (25) for measuring and establishing an upstream actual filter cake moisture value for filter cake (60) formed by the filter (5); and

a downstream moisture analyzer (26) for measuring and establishing a downstream actual filter cake moisture value for filter cake (61) conveyed by a conveyor (7, 8) for a period of time and exposed to environmental elements for that same period of time;

wherein in operation, the executable algorithm (10) is configured to autonomously change a belt speed of the conveyor (7,8), if there is a difference between the upstream and downstream actual filter cake moisture values which falls outside of an acceptable range.

10. The filtration system (1) according to any one of claims 7-9, wherein the executable operating algorithm (10) is configured to receive a number of inputs (11), and deliver a number of outputs (12), based on the inputs (11).
- 5 11. The filtration system (1) according to claim 10, wherein the inputs (11) include meteorological data selected from one or more of the group consisting of: current relative % humidity, forecasted relative % humidity, current % chance of precipitation, forecasted % chance of precipitation, current temperature, forecasted temperature(s), current percent sky cover, forecasted percent sky
- 10 cover, current UV index, forecasted UV index, current type of precipitation falling, type of precipitation (e.g., snow, rain, sleet, hail, wintry mix, freezing fog) forecasted, current wind speed(s), forecasted wind speed(s), current wind direction(s), forecasted wind direction(s), current precipitation totals, and forecasted total amounts of accumulated precipitation over a specified duration of
- 15 time into the future; and
- wherein the outputs (12) include an instruction for controlling the belt speed of a conveyor (7, 8) moving filter cake (60, 61) produced by the filtration process.
- 20 12. The method of controlling a filtration process substantially shown and described in FIGS 1-8.
13. The method of controlling a filtration process substantially shown and described in FIGS 9-15.
14. The filtration system (1) substantially shown and described.

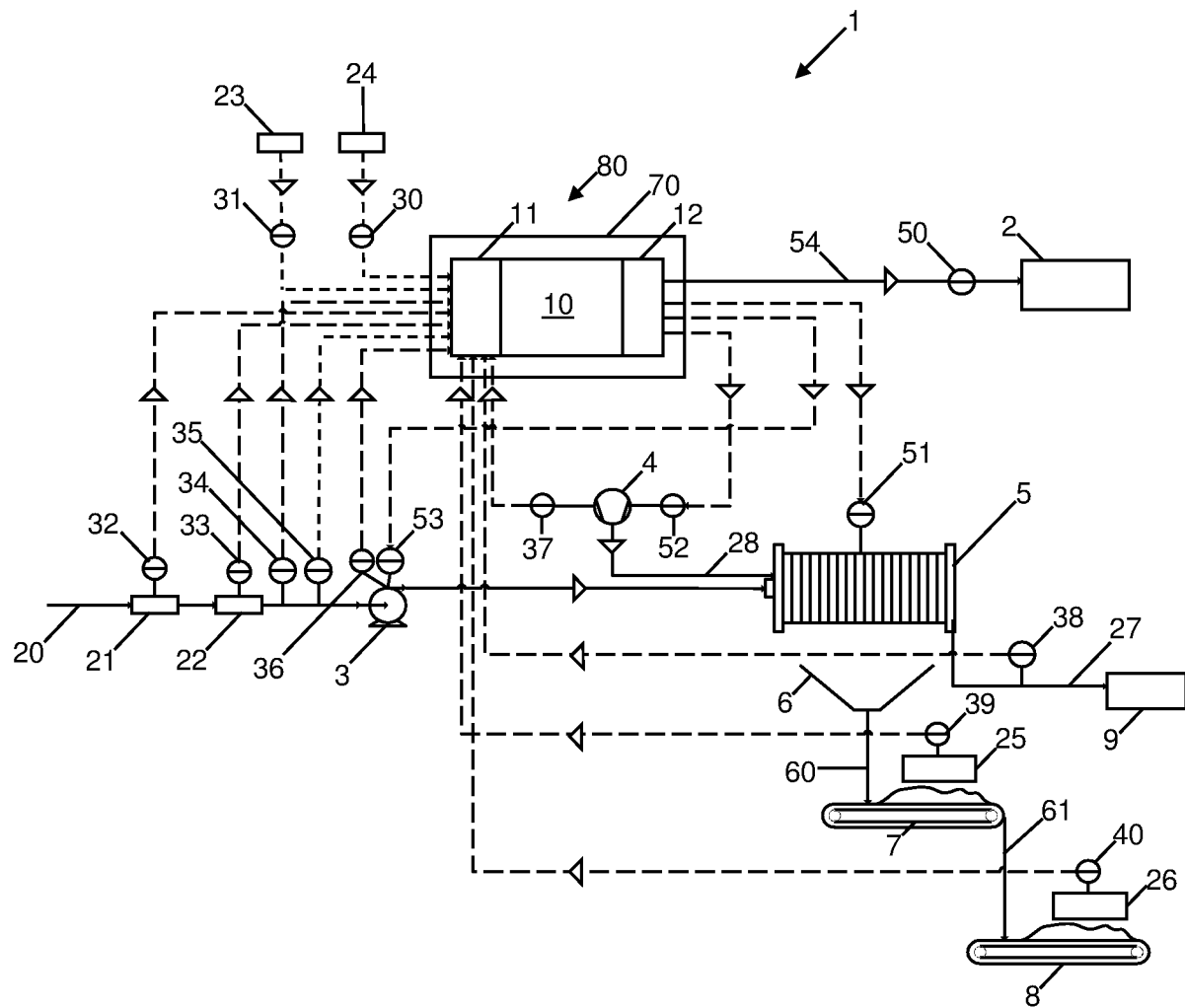


FIG. 1

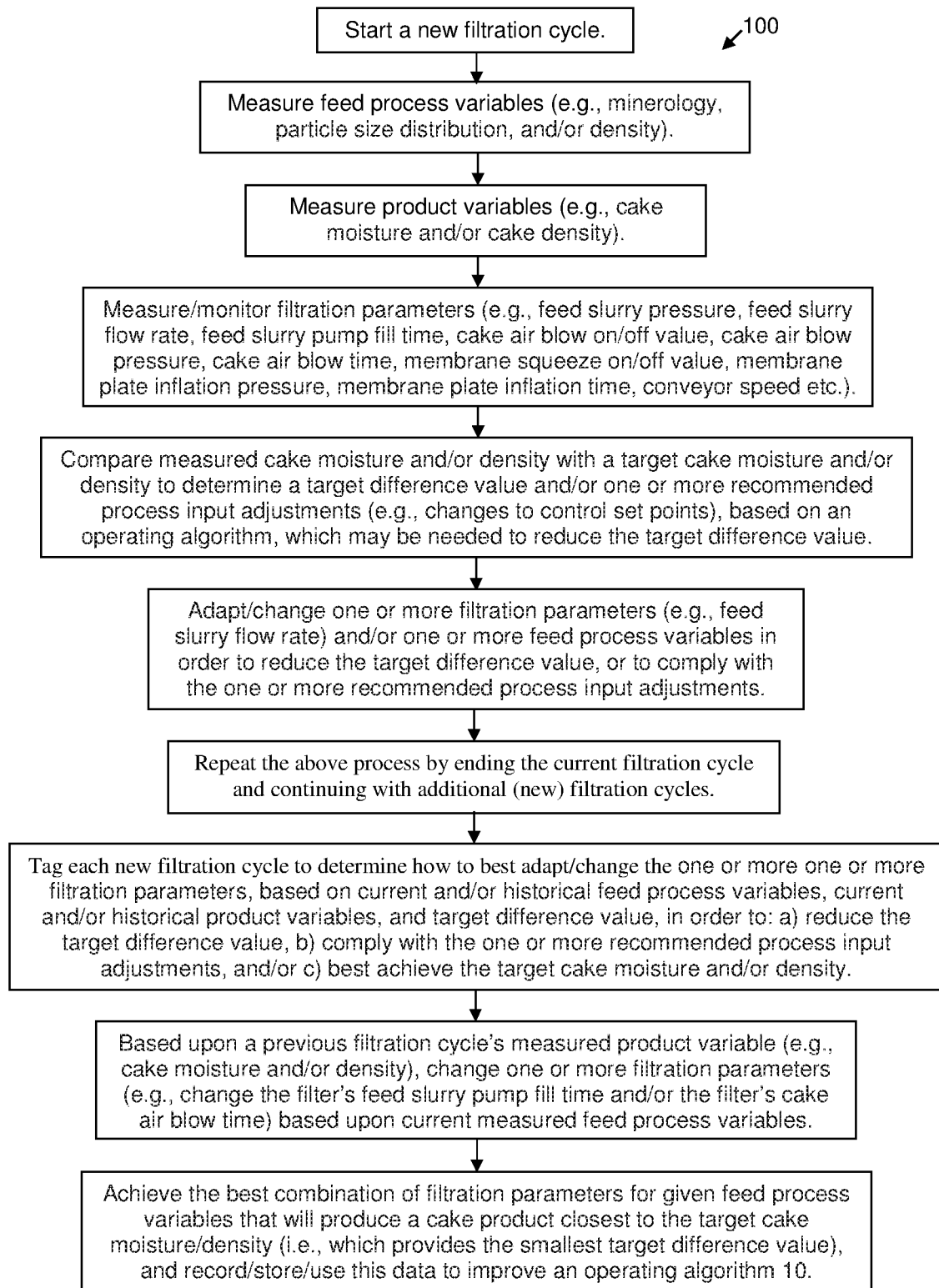


FIG. 2

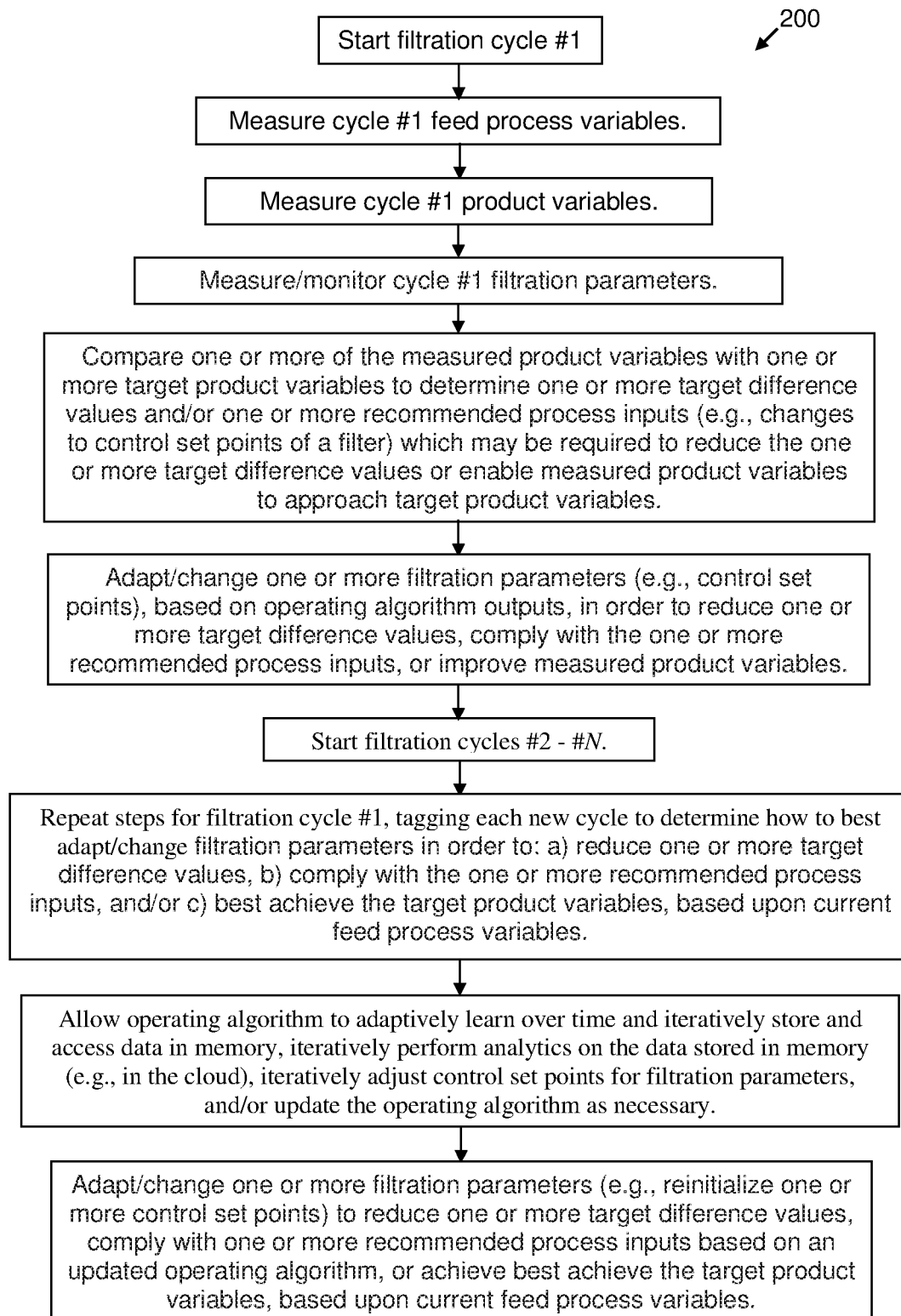


FIG. 3

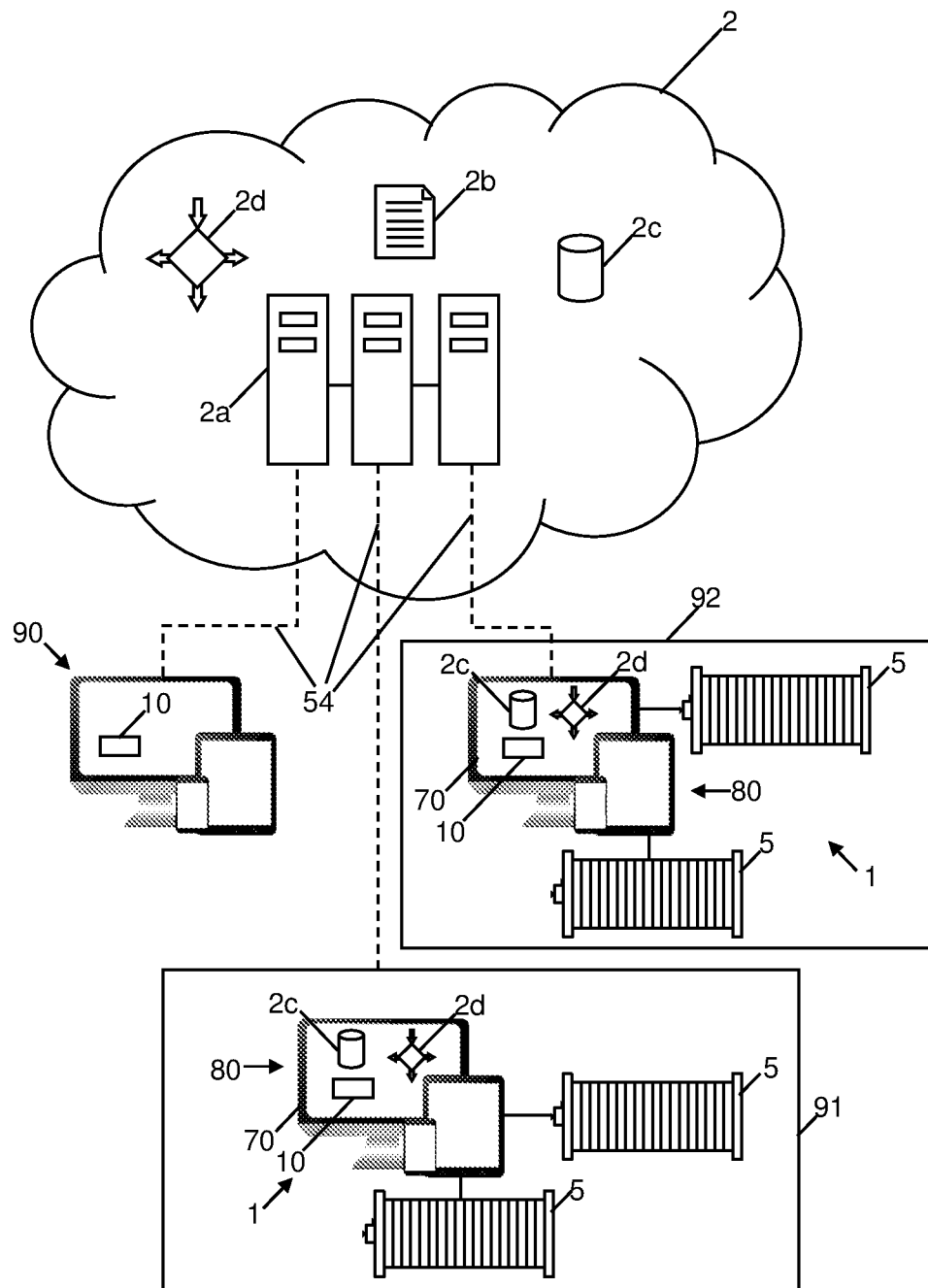


FIG. 4

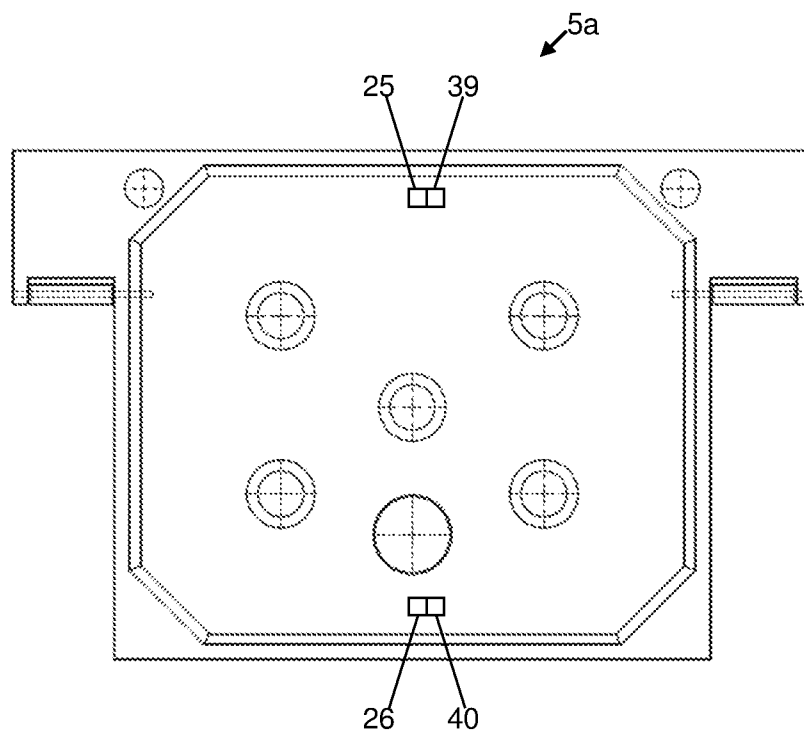


FIG. 5

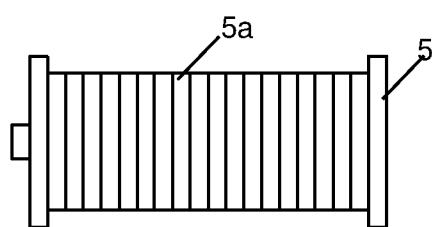


FIG. 6

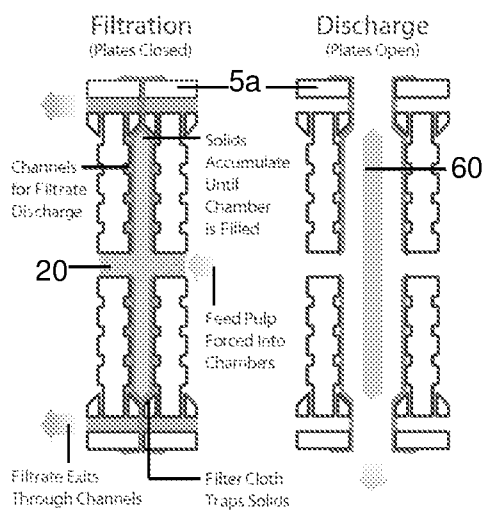


FIG. 7

1. Establish a target filter cake moisture content M_t
2. Establish a function: Cake moisture content = a function of one or more control set points (e.g., $f_M(X_1, X_2, X_3, X_4, X_5, \dots, X_n)$, where each set point comprises a feed process variable value, filtration parameter value, product variable value, or the like
3. Change the function f_M over time, based on big data analytics, using past performance data stored in a database
4. Perform the following for 1 to N -number of filtration cycles:

- a. Determine an independent actual filter cake moisture content m_i from a reading/measurement during the filtration cycle
- b. Compare M_t with m_i

If m_i is less than M_t and convergence is not satisfactory:

1. Calculate m_x , the midpoint of the interval between m_i and M_t , $m_x = m_i + M_t / 2$
2. Set function f_M equal to m_x and back solve for the one or more control set points (e.g., $X_1, X_2, X_3, X_4, X_5, \dots, X_n$), using an operating algorithm.
3. Adjust one or more control set points to save/reduce energy during the next filtration cycle (e.g., reduce one or more filtration parameters, reduce the duration time of one or more filtering steps, reduce filtration cycle time, remove one or more filtering steps, reduce pressure, reduce flow, etc.)

Else, if m_i is greater than M_t and convergence is not satisfactory:

1. Calculate m_x , the midpoint of the interval between m_i and M_t , $m_x = m_i + M_t / 2$
2. Set function f_M equal to m_x and backsolve for the one or more control set points (e.g., $X_1, X_2, X_3, X_4, X_5, \dots, X_n$), using an operating algorithm.
3. Increase one or more control set points to increase energy use and increase dewatering during the next filtration cycle (e.g., increase one or more filtration parameters, reduce the duration time of one or more filtering steps, reduce filtration cycle time, remove one or more filtering steps, reduce pressure, reduce flow, etc.)

Else, if convergence is satisfactory (e.g., $m_x - m_i$ is sufficiently small, $M_t - m_x$ is sufficiently small, or $M_t - m_i$ is sufficiently small):

1. Leave one or more control set points alone to maintain current energy use and amount of dewatering during the next filtration cycle (e.g., leave filtration parameters alone, do not change duration time of one or more filtering steps, filtration cycle time, one or more filtering steps, pressure values, flow values, etc.)

- c. Run another filtration cycle

FIG. 8

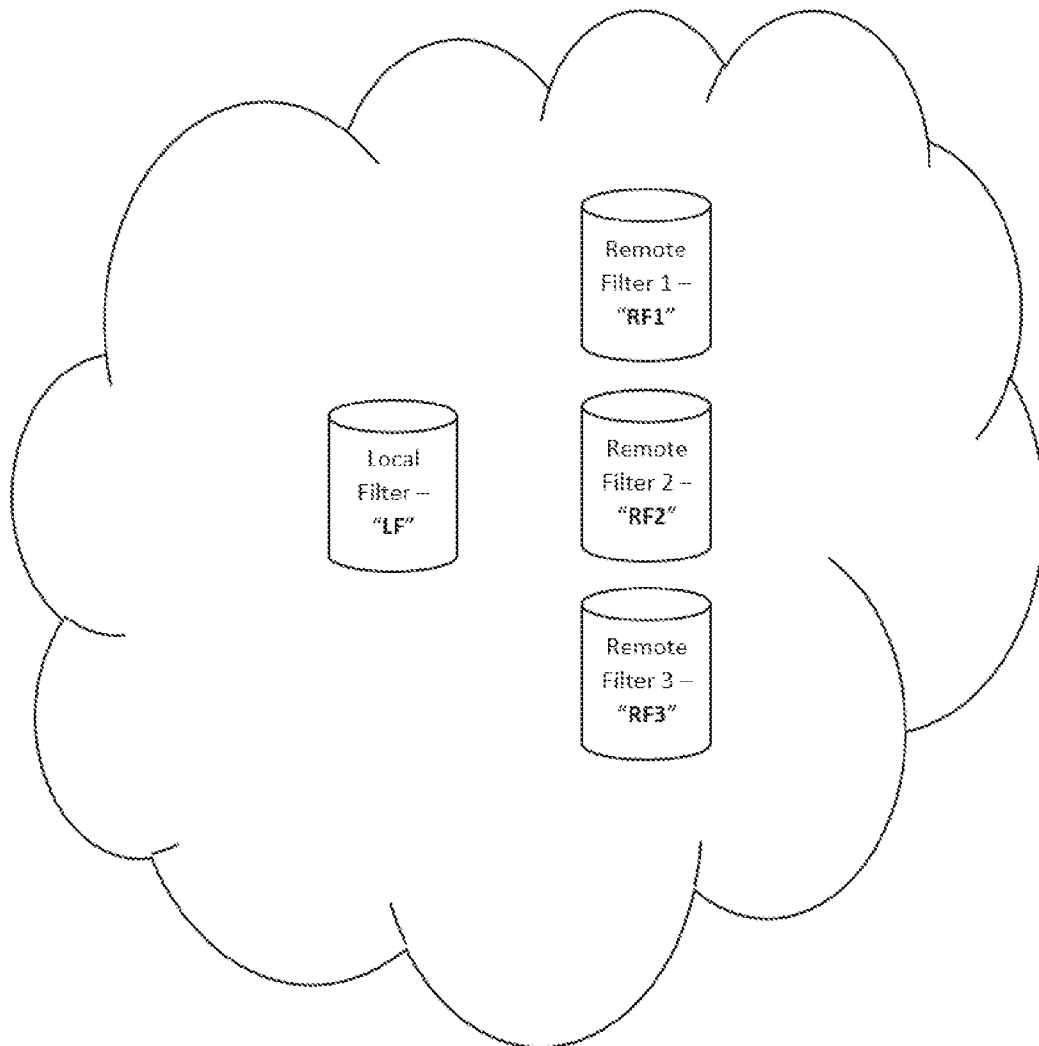


FIG. 9

Local Filter – “**LF**” (Maximum Target % H2O)

Cycle #	% H2O	% Quartz	% Clay	PSD	Feed p	Set Point 1 value	Set Point 2 value	Set Point 3 value
1	A ₁	B ₁	C ₁	D ₁	E ₁	F ₁	G ₁	H ₁
2	A ₂	B ₂	C ₂	D ₂	E ₂	F ₂	G ₂	H ₂
3	A ₃	B ₃	C ₃	D ₃	E ₃	F ₃	G ₃	H ₃
4	A ₄	B ₄	C ₄	D ₄	E ₄	F ₄	G ₄	H ₄
5	A ₅	B ₅	C ₅	D ₅	E ₅	F ₅	G ₅	H ₅
6	A ₆	B ₆	C ₆	D ₆	E ₆	F ₆	G ₆	H ₆
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
N	A _N	B _N	C _N	D _N	E _N	F _N	G _N	H _N

CURRENT FILTRATION CYCLE 

FIG. 10

Remote Filter 1 - "RF1" Stored Data

Cycle #	% H2O	% Quartz	% Clay	PSD	Feed p	Set Point 1 value	Set Point 2 value	Set Point 3 value
1	A ₁	B ₁	C ₁	D ₁	E ₁	F ₁	G ₁	H ₁
2	A ₂	B ₂	C ₂	D ₂	E ₂	F ₂	G ₂	H ₂
3	A ₃	B ₃	C ₃	D ₃	E ₃	F ₃	G ₃	H ₃
4	A ₄	B ₄	C ₄	D ₄	E ₄	F ₄	G ₄	H ₄
5	A ₅	B ₅	C ₅	D ₅	E ₅	F ₅	G ₅	H ₅
6	A ₆	B ₆	C ₆	D ₆	E ₆	F ₆	G ₆	H ₆
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

FIG. 11

Remote Filter 2 - "RF1" Stored Data

Cycle #	% H2O	% Quartz	% Clay	PSD	Feed p	Set Point 1 value	Set Point 2 value	Set Point 3 value
1	A ₁	B ₁	C ₁	D ₁	E ₁	F ₁	G ₁	H ₁
2	A ₂	B ₂	C ₂	D ₂	E ₂	F ₂	G ₂	H ₂
3	A ₃	B ₃	C ₃	D ₃	E ₃	F ₃	G ₃	H ₃
4	A ₄	B ₄	C ₄	D ₄	E ₄	F ₄	G ₄	H ₄
5	A ₅	B ₅	C ₅	D ₅	E ₅	F ₅	G ₅	H ₅
6	A ₆	B ₆	C ₆	D ₆	E ₆	F ₆	G ₆	H ₆
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

FIG. 12

Remote Filter 3 - "RF1" Stored Data

Cycle #	% H2O	% Quartz	% Clay	PSD	Feed p	Set Point 1 value	Set Point 2 value	Set Point 3 value
1	A ₁	B ₁	C ₁	D ₁	E ₁	F ₁	G ₁	H ₁
2	A ₂	B ₂	C ₂	D ₂	E ₂	F ₂	G ₂	H ₂
3	A ₃	B ₃	C ₃	D ₃	E ₃	F ₃	G ₃	H ₃
4	A ₄	B ₄	C ₄	D ₄	E ₄	F ₄	G ₄	H ₄
5	A ₅	B ₅	C ₅	D ₅	E ₅	F ₅	G ₅	H ₅
6	A ₆	B ₆	C ₆	D ₆	E ₆	F ₆	G ₆	H ₆
.	.	.	.	.	.	.	.	.
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.	.	.	.	.	.	.	.	.

FIG. 13

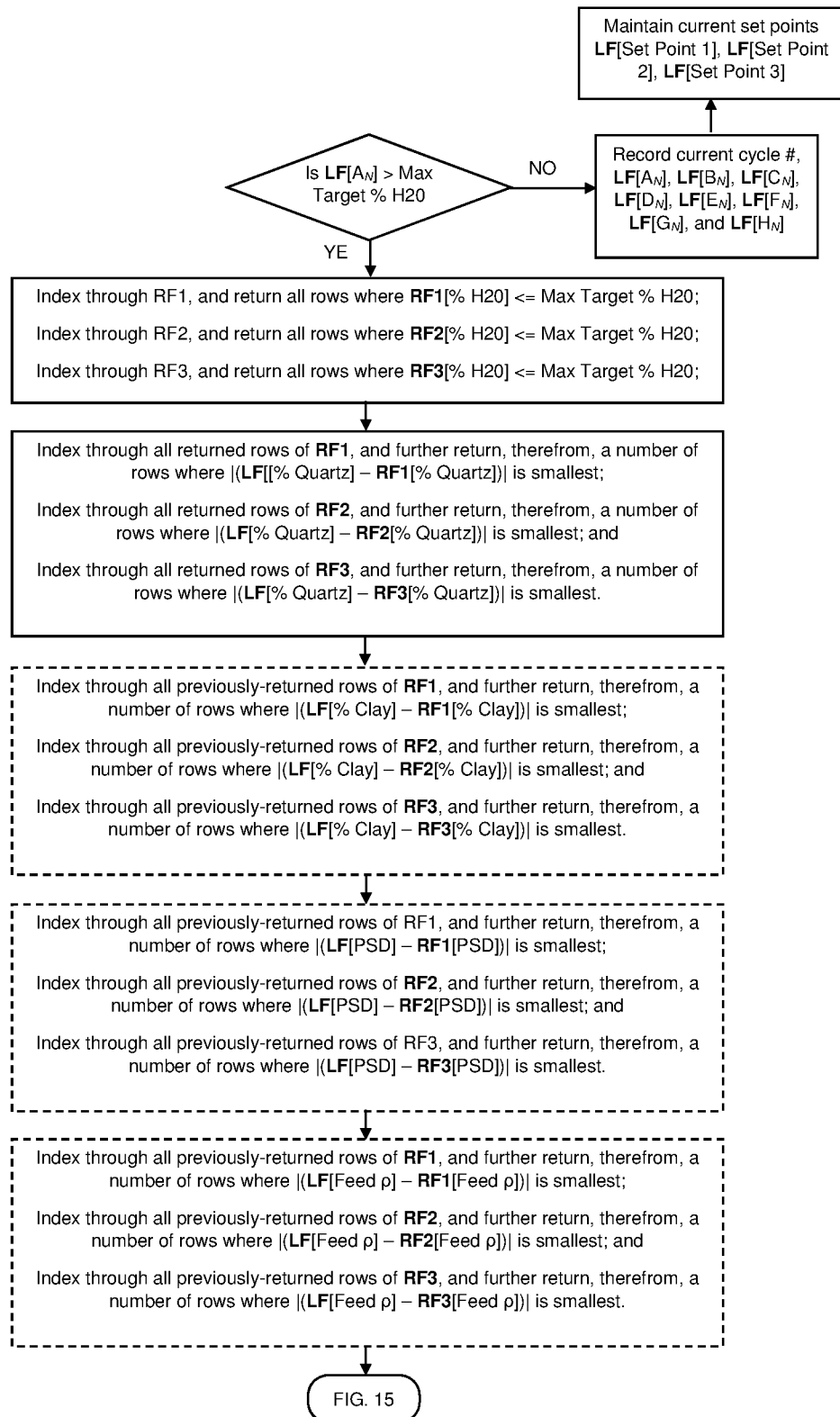


FIG. 14

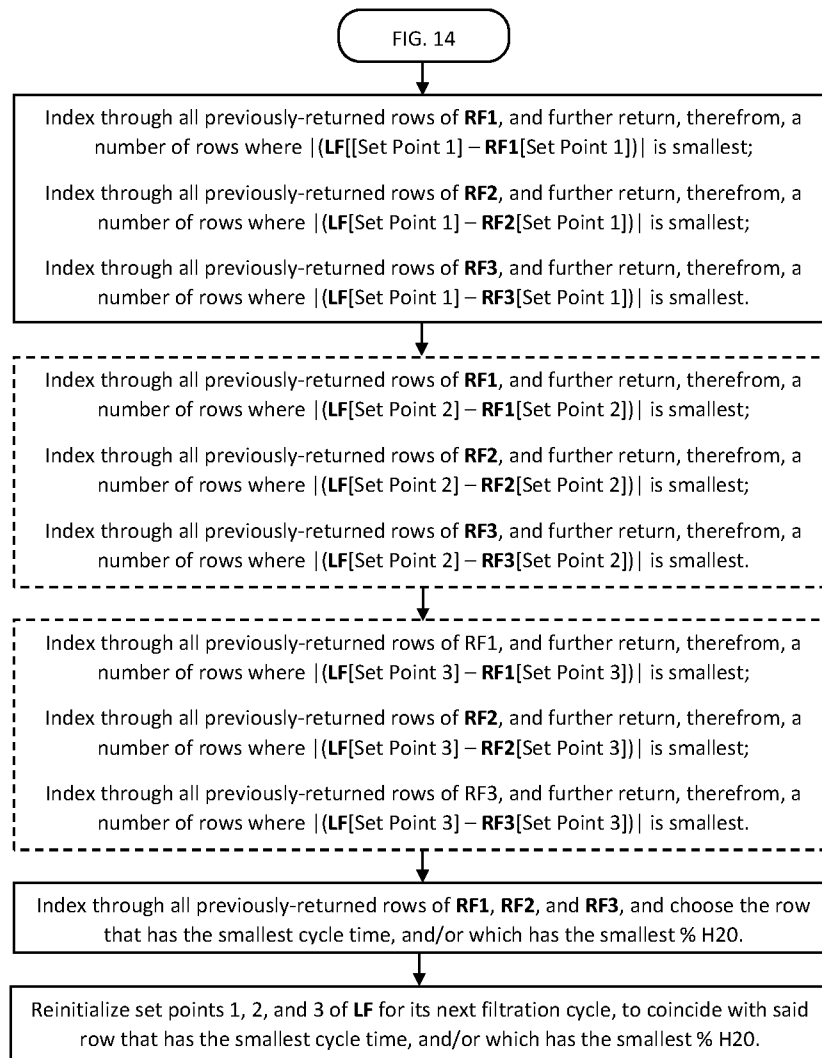


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/051400

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D25/00 B01D25/164 B01D25/28
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)
B01D

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)

EP0-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.
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X	----- US 5 380 440 A (CHIPPS EVAN R [ZA]) 10 January 1995 (1995-01-10) the whole document	1-6,8-11
X	----- EP 0 759 318 A1 (MUT MILJOEVERN UMWELT TECHNIK [DE]) 26 February 1997 (1997-02-26) the whole document	1,2,4,5, 7,10
	----- -/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

30 March 2020

Date of mailing of the international search report

09/04/2020

Name and mailing address of the ISA/

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Authorized officer

Hilt, Daniel

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/051400

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2020/051400

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