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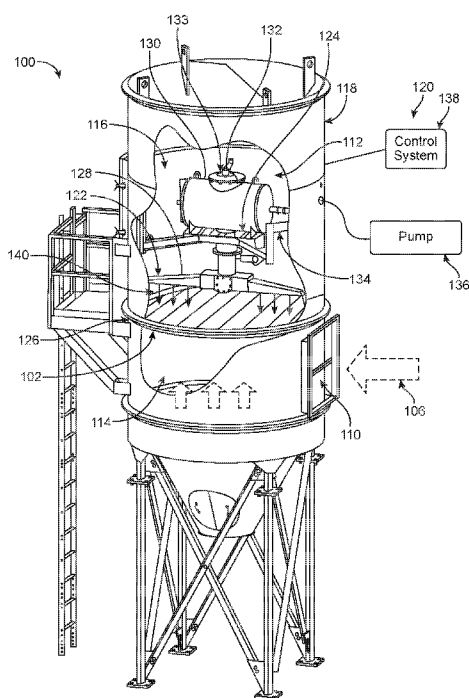


FIG. 1

(57) Abstract: A filter system includes a tube sheet defining a plurality of holes in fluid communication with a plurality of filter bags. The system also includes a rotating assembly having an arm defining one or more outlets to provide pressurized air from an air source toward the tube sheet in response to pulsing one or more actuators. A motor is operably coupled to the stationary assembly and the rotating assembly to rotate the arm about an axis at a preset rotational speed. A controller is operably coupled to the motor and the one or more actuators to provide pulse commands based on a pulse interval and a jog interval. The pulse interval and the jog interval may be determined based on a measured rotational speed of the arm, which may be redetermined during operation.



PULSE DELIVERY CLEANING SYSTEMS AND METHODS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/820,394, filed 19 March 2019, the disclosure of which is incorporated by reference herein in its entirety.

[0002] The present technology is generally related to filter systems and, in particular, to the control of pulse delivery cleaning systems for bag house filters.

[0003] Dust collectors are used to clean particulate matter from airflow streams. One embodiment of dust collectors includes bag house filters. Bag house filters include: a housing, a dirty air inlet, a clean air outlet, and a tube sheet having a plurality of apertures. The tube sheet separates the housing between a dirty air side and a clean air side and holds filter bags. The bags, or filter bags, are made of a filter media so that as dirty air flows from the dirty air side to the clean air side, the air must flow through the bags and the filter media of the bags prevents particulate matter from reaching the clean air side. Periodically, the particulate laden bags are pulse cleaned to achieve continuous duty operation of filtering.

SUMMARY

[0004] This disclosure generally relates to pulse delivery cleaning systems and methods for bag house filters that may require less maintenance and need fewer adjustments, as well as facilitating ease of manufacturing.

[0005] In one aspect, the present disclosure provides a system including a stationary assembly having a tube sheet defining a plurality of holes in fluid communication with a plurality of filter bags and further having one or more actuators each configured to release pressurized air in response to a pulse command. The system also includes a rotating assembly having an arm defining one or more outlets positioned along a length of the arm. The one or more outlets are configured to provide pressurized air from an air source toward the tube sheet in response to the one or more actuators receiving a pulse command. The system also includes a motor operably coupled to the stationary assembly

and the rotating assembly configured to rotate the arm about an axis at a preset rotational speed. The system also includes a controller operably coupled to the motor and the one or more actuators. The controller includes a processor configured to: provide a set of pulse commands to the one or more actuators to provide a set of pulses over one or more revolutions of the arm, determine a jog interval between the set of pulse commands and a subsequent set of pulse commands based on a measured rotational speed of the arm, and provide, after waiting one jog interval, the subsequent set of pulse commands to the one or more actuators to provide a subsequent set of pulses over one or more subsequent revolutions of the arm.

[0006] In another aspect, the present disclosure provides an apparatus including an input interface, an output interface, a memory, and a processor operably coupled to the input interface, the output interface, and the memory. The processor is configured to determine a rotational speed of an arm based on measurements from a position sensor assembly using the input interface. The arm defining one or more outlets are configured to release pressurized air in response to one or more actuators receiving a pulse command. The processor is also configured to determine a pulse interval and a jog interval based on the rotational speed of the arm. The pulse interval defines an interval between pulse commands in one set of pulse commands. The jog interval defines an interval between a set of pulse commands and a subsequent set of pulse commands. The processor is also configured to store the pulse interval and the jog interval into the memory. The processor is also configured to provide the subsequent set of pulse commands based on the pulse interval and the jog interval to the one or more actuators using the output interface to release the subsequent set of pulses of pressurized air through the one or more outlets.

[0007] In another aspect, the present disclosure provides a method including revolving an arm about an axis. The arm defining one or more outlets positioned along a length of the arm. The one or more outlets are configured to direct pressurized air from an air source toward a tube sheet. The tube sheet defines a plurality of holes in fluid communication with a plurality of filter bags. The method also includes releasing a set of pulses of pressurized air from the one or more outlets over one or more revolutions of the arm. The method also includes determining a jog interval between the set of pulses and a

subsequent set of pulses of pressurized air based on a measured rotational speed of the arm. The method also includes releasing, after waiting one jog interval, the subsequent set pulses from the one or more outlets over one or more subsequent revolutions of the arm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] **FIG. 1** is a perspective cutaway view of one example of a dust collector utilizing a pulse delivery cleaning system.

[0009] **FIG. 2** is a perspective view of one example of a tube sheet that may be used in the dust collector of **FIG. 1** that may be cleaned by the pulse delivery cleaning system.

[0010] **FIG. 3** is a schematic partial cross-sectional view of the dust collector of **FIG. 1**.

[0011] **FIG. 4** is a schematic overhead view of the spokes of the tube sheet of **FIG. 2**.

[0012] **FIG. 5** is a schematic diagram of one example of a control system that may be used with the dust collector of **FIG. 1**.

[0013] **FIG. 6** is a flowchart of one example method of operating the pulse delivery cleaning system of **FIG. 1**.

DETAILED DESCRIPTION

[0014] The present disclosure relates to filter systems and, in particular, control of pulse delivery cleaning systems for filters. Existing pulse delivery cleaning systems for dust collectors, such as round bag house systems, use motors and gearboxes to rotate an arm for pulse delivery cleaning, which may be susceptible to mechanical slip, mechanical failures, or other conditions that affect the position or rotational speed of the arm over long periods of time. As little as one-percent slip from the preset rotational speed can cause a complete miss of a set of filter bags in one rotation of the arm, or at least inefficient release of pulses over some filter bags. The pulse cleaning delivery system may require adjustment, or even repair, to return to desirable performance. Complex motors or gearboxes may be used to facilitate accurate and precise rotation of the arm to

deliver pulses to the filter bags, which may affect the manufacturability of these systems and may result in higher high failure rates.

[0015] The techniques of this disclosure provide a control system and method for pulse delivery cleaning based on actual rotation of the arm to maintain accurate pulse delivery to clean the filter bags. In other words, these techniques provide for adjustments in pulse delivery cleaning in response to one or more measurements related to the arm. The control system measures an actual rotational speed of the arm using a position sensor, such as a proximity sensor. A pulse interval is calculated to deliver pulses when the arm is aligned over a set of filter bags based on the measured rotational speed of the arm so that pulses can be consistently delivered to the “dead center” of the openings of the filter bags over long periods of time. In some embodiments, a jog interval is determined that may be used in place of one, or in between some, of the pulse intervals, which shifts a set of subsequent delivered pulses and may facilitate complete, even cleaning of the filter bags. The pulse interval and the jog interval may be redetermined during operation based on further measurements of the rotational speed of the arm. In general, the pulse delivery cleaning systems that have control systems or use methods described herein may be manufactured more easily and require less maintenance and down time than some existing pulse delivery cleaning systems to operate at desirable performance over long periods of time.

[0016] Reference will now be made to the drawings, which depict one or more aspects described in this disclosure. However, it will be understood that other aspects not depicted in the drawings fall within the scope of this disclosure. Like numbers used in the figures may refer to like components, steps, and the like. However, it will be understood that the use of a reference character to refer to an element in a given figure is not intended to limit the element in another figure labeled with the same reference character. In addition, the use of different reference characters to refer to elements in different figures is not intended to indicate that the differently referenced elements cannot be the same or similar.

[0017] As used herein, the term “or” is generally employed in its inclusive sense, for example, to mean “and/or” unless the context clearly dictates otherwise. The term

“and/or” means one or all the listed elements or a combination of at least two of the listed elements.

[0018] Various embodiments of the present disclosure relate to filter systems, such as round dust collectors or round bag house systems. Although the pulse delivery cleaning techniques described herein may be used with any suitable filter system, one example of a round bag house filter system is shown in **FIG. 1** to facilitate understanding of these techniques.

[0019] **FIGS. 1-4** show various views of one example of a filter system **100**, which is a round bag house filter system. **FIG. 1** shows a cutaway perspective view of the filter system **100** having a tube sheet **102** used to clean an airflow **106** by removing dust or other particulates. The tube sheet **102** has a surface that is illustrated schematically with line shading, whereas more detail is shown in **FIG. 2**. In **FIG. 2**, the tube sheet **102** is shown having a plurality of holes **108** and a plurality of filter bags **104** coupled to the tube sheet to cover the holes. The holes **108** and the filter bags **104** coupled to the holes are arranged into radial spokes **152** and concentric rings **154** along the surface of the tube sheet **102**. **FIG. 3** shows a schematic cross-sectional view of one or more outlets **160** of an arm **128** positioned over different rings **154** of the holes **108**. **FIG. 4** shows an overhead view of the tube sheet **102** and the rotation of the arm **128** in relation to the spokes **152**. In the illustration, each spoke **152** is shown as a wedge, or slice, of the circle. Although, the lead lines from **152** shown in **FIG. 4** point to only three of the plurality of spokes illustrated, all the wedges represent spokes **152** in this illustration.

[0020] In general, the filter system **100** filters dust from the airflow **106** that passes through the plurality of filter bags **104** and through the plurality of holes **108**, or apertures, defined in the tube sheet **102** that are in fluid communication with the filter bags. The filter bags **104** may be cleaned from time-to-time using pulse cleaning to extend their working life.

[0021] As can be seen in **FIG. 1**, in operation, the airflow **106** including dirty air is drawn through a dirty air inlet **110** into a housing **118** by way of a blower arrangement (not shown). The airflow **106** moves into an interior volume **112** of the housing **118**. The airflow **106** may start in a dirty air volume **114** of the interior volume **112** on the dirty air

side of the tube sheet **102**. The airflow **106** may pass downstream (the “up” direction in the illustration) through the filter bags **104** (**FIG. 2**) coupled to the tube sheet **102**, where dust and debris are removed from the airflow. The airflow **106** including filtered air then flows into a clean air volume **116** of the interior volume **112** on a clean air side of the tube sheet **102**. The tube sheet **102** and the plurality of filter bags **104** coupled to the tube sheet divide the interior volume **112** and separate the dirty air volume **114** from the clean air volume **116**. The airflow **106** including the filtered air then exits a housing **118** of the filter system **100** through a clean air outlet (not shown).

[0022] The housing **118** may have a generally cylindrical structure surrounding the interior volume **112**. The dirty air inlet **110** and the clean air outlet may be defined by the housing **118**. The tube sheet **102** may be mechanically coupled to the housing **118** and may have a round circular structure that complements the interior shape of the housing **118** to form a seal around its perimeter with the housing.

[0023] The blower arrangement directs air from the dirty air inlet **110** to the clean air outlet. In some embodiments, the blower arrangement may create a vacuum at the clean air outlet. The blower arrangement may be located remotely from the housing **118** but connected in fluid, or airflow, communication by duct work to the clean air outlet.

[0024] The filter system **100** may also include a dust collection hopper oriented in communication with the interior volume **112** and below the housing **118**. The hopper may have a frusto-conical structure. The hopper collects dust and debris separated from the air. A support structure, such as legs or other support beams oriented to support the housing **118** and hopper, may be included. Typically, the housing **118** and hopper are supported vertically above the ground such that a drum or some other container can be placed underneath the hopper to empty the hopper of dust and debris.

[0025] A ladder may be provided for accessing the interior volume **112** of the housing **118**. The ladder may extend to a platform. The person servicing the filter system **100** can climb the ladder, stand on the platform, and then open a service door, which provides access to the interior volume **112**. In the illustrated embodiment, the service door provides access to a clean air volume **116** of the interior volume **112**.

[0026] The filter system **100** includes a pulse delivery cleaning system **120** to provide one full clean cycle of the filter bags **104** over a time period defined as a full clean time. In the illustrated embodiment, the pulse delivery cleaning system **120** includes a rotating assembly **122** that rotates about a central axis **150** (FIGS. 2-4) by a motor **124** to deliver pressurized pulses **140** of air through different holes **108** in the tube sheet **102** to the filter bags **104** for cleaning. In general, the rotating assembly **122** includes one or more components that rotate in response to running the motor **124**. The pulse delivery cleaning system **120** may also include a stationary assembly **126**, which includes one or more components of the filter system **100** that do not rotate in response to running the motor **124**. The motor **124** may be operably coupled to either or both of, or between, the stationary assembly **126** and the rotating assembly **122**.

[0027] The rotating assembly **122** may include an arm **128** that has a generally linear elongate structure extending laterally, or perpendicular, to the axis **150**. The stationary assembly **126** may include the housing **118**, the tube sheet **102**, a compressed air tank **130**, at least one actuator **132**, a mounting structure **134** that is coupled to the housing **118** to support one or more components of the filter system **100** in the clean air volume **116**, an air compressor pump **136**, which may be located outside of the housing **118**, a control system **138**, or any other stationary structure of the filter system **100**.

[0028] The arm **128** may be rotatably coupled to the mounting structure **134** to support the arm above the tube sheet **102** in the clean air volume **116**. The motor **124** may be operably coupled to the arm **128** and the mounting structure **134** to rotate the arm about the axis **150** when in operation.

[0029] The arm **128** may include an arm housing defining a volume of an air distribution header within the arm housing. One or more outlets **160** may be positioned, or defined, along a length of the arm **128** that are in selective fluid communication with the air distribution header, the tank **130**, and the pump **136**. One or more diaphragm valves may be used to selectively separate the outlets **160** from one or more of the air distribution header, the tank **130**, or the pump **136**, which may be opened or closed using at least one actuator **132**. The outlets **160** may include apertures defined by the arm housing or nozzles extending from the arm housing. The pulse delivery cleaning system

120 may provide a jet of pressurized air from an air source, such as the tank **130** or pump **136**, through the air distribution header in the arm housing, and through the outlets **160**.

[0030] In one or more embodiments, each of the filter bags **104** is oriented to extend from the tube sheet **102** into the dirty air volume **114**. The filter bag **104** may be removably mounted to the tube sheet **102**, such that after a period of use, the filter bag **104** can be removed and replaced with a new filter bag when the working life of the filter bag has expired. The arm **128** directs a jet of pressurized air upstream (the “down” direction as illustrated) through the one or more outlets **160** into at least one of the holes **108** in the tube sheet **102** and at least one corresponding filter bag **104** to remove at least some of the dust and debris from the dirty side of the filter bag to clean the filter bag. In other words, the pulses **140** of pressurized air are directed in a direction opposite to the airflow **106** through the filter bags **104** and the holes **108**. The dust and debris may fall by gravity into the hopper. In this manner, the filter system **100** may operate for a longer period of time before replacement of the filter bag **104** compared to a system without the pulse delivery cleaning system **120**.

[0031] As can be seen in **FIG. 2**, the holes **108** and the corresponding filter bags **104** may be arranged into one or more radial spokes **152**. The spokes **152** may extend along a line that intersects with the axis **150**. Each spoke **152** may include one or more holes **108**. Each spoke **152** may have the same or a different number of holes **108** than the other spokes. In the illustrated embodiment, the spokes **151** and **155** have ten holes each (five on each side of the axis **150**), and the spokes **153** and **157** have fourteen holes each (seven on each side of the axis). The arm **128** momentarily aligns to each of the spokes **152** during each revolution.

[0032] The holes **108** and the corresponding filter bags **104** may further be arranged into concentric rings **154**. Each ring **154** may have a circular shape centered at the axis **150**. Each ring **154** may have the same or a different number of holes **108** than the other rings. In the illustrated embodiment, the rings **159** and **161** have twenty-four holes each, whereas the ring **163** has twelve holes. In general, rings **154** closer to the axis **150** may have a smaller diameter and fewer holes **108** than rings further from the axis near the periphery of the tube sheet **102**.

[0033] Each of the outlets **160** of the arm **128** may be aligned to a different ring **154** and aligned to pass over a center of each hole **108** in the respective ring. The arm **128** may include or define one or more segments. As can be seen in **FIG. 3**, the arm **128** may include a first segment **156** and a second segment **158** extending opposite to the first segment. The outlets **160** on the first segment **156** may be aligned to a first subset **162** of the holes **108** arranged into concentric rings **154**, and the outlets **160** on the second segment **158** may be aligned to a second subset **164** of the holes **108** arranged into concentric rings **154**. For example, if the concentric rings **154** were numbered from the innermost ring to the outermost ring from one to seven, the outlets **160** of the first segment **156** would be aligned to the odd rings (1, 3, 5, 7) and the outlets **160** of the second segment **158** would be aligned to the even rings (2, 4, 6). One complete revolution of the arm **128** may be used to pass each outlet **160** over each hole **108** in each concentric ring **154**.

[0034] The air tank **130** may be coupled to the mounting structure **134** and mounted inside the clean air volume **116**. In other embodiments, the air tank **130** may be mounted outside of the housing **118**, for example, on a roof of the housing. The air tank **130** may be operably coupled to the pump **136**, which pressurizes air to store in the tank. The air tank **130** may be operably connected in fluid communication to the one or more outlets of the arm **128** to provide pressurized pulses **140** of air to the one or more outlets.

[0035] The at least one actuator **132** may be coupled to the tank **130** and at least one diaphragm. The at least one actuator **132** is configured to receive a pulse command and provide a set of pressurized pulses **140** from the arm **128**, for example, by lifting a diaphragm to allow pressurized air from the tank **130** to flow through the one or more outlets along the arm **128**. In one or more embodiments, one or more diaphragm valves **133** may be coupled to the tank **130** or the arm **128**. Each of the diaphragm valves **133** may include one or more diaphragms positioned as a seal between two volumes. A diaphragm valve **133** may be opened using an actuator, such as a solenoid, to release pressure on one side of a diaphragm and opens the diaphragm valve. Opening of the one or more diaphragm valves **133** may fluidly connect the tank **130** and the outlets **160** of the arm **128**. In the illustrated embodiment, the double-diaphragm setup uses two diaphragm valves **133** positioned on top of the tank including a small diaphragm valve,

which may be opened using a solenoid to open a large diaphragm valve, which fluidly connects the tank **130** to the arm **128** allowing airflow from the tank **130** to the outlets **160** of the arm **128**.

[0036] As used herein, a “set of pulses” or “set of pressurized pulses” or “set of pressurized pulses of air” refers to one pulse of pressurized air from each of the one or more outlets **160** of the arm **128**. In the illustrated embodiment, one actuator **132** may be used to provide all pressurized pulses **140** from the arm **128** at a time. In other embodiments, the at least one actuator **132** is coupled to the rotating assembly **122** instead of the stationary assembly **126**. In other embodiments, more than one actuator **132** and more than one diaphragm valve **133** may be used to provide the set of pressurized pulses **140** from the arm **128**.

[0037] The actuator **132** may open the diaphragm for a predetermined duration to provide the set of pressurized pulses **140** from the pressurized air in the tank **130**. After the actuator **132** provides the set of pressurized pulses **140**, the diaphragm may be closed by the actuator for a time interval to allow the tank **130** to pressurize again. The arm **128** may continue to rotate while the diaphragm is closed to position the arm over a different set of holes **108** of the tube sheet **102**. The actuator **132** may open the diaphragm at a later time after the interval, or when the time interval expires, for the same predetermined duration to provide a subsequent set of pressurized pulses to the different set of holes **108**. The alternating of open and closed states of the diaphragm by the actuator **132** may be repeated periodically as the arm **128** rotates to provide a plurality of pulses to clean all the filter bags **104** in the filter system **100**.

[0038] The pump **136** may be appropriately sized to pressurize the tank **130** to a desired pressure between subsequent pulses, for example, based on a desired full clean time and the number of spokes **152**. In general, when the filter system **100** is larger and has more filter bags **104**, the size of the tank **130** and the capacity of the pump **136** are also increased to maintain a similar full clean time for all the filter bags **104**.

[0039] In some embodiments, a relief valve or pressure sensor (not shown) may be coupled to the tank **130** to determine medium pressure in the tank **130**. A relief valve may help to regulate pressure in the tank **130**. The filter system **100** may be designed to

minimize the number of times that such a valve is opened to regulate pressure in the tank **130**. In some cases, opening the relief valve may create an undesirable level of noise.

[0040] As can be seen in **FIGS. 3-4**, the filter system **100** may include a position sensor assembly **180** that, when activated or triggered, provides an indication of the location of the arm **128**. The position sensor assembly **180** may be operably coupled to the control system **138** to provide measurements related to rotation of the arm **128**. The position sensor assembly **180** may include a first part **182** and a second part **184**. The first part **182** may be coupled to the stationary assembly **126** and in a fixed location, and the second part **184** may be coupled to the rotating assembly **122** and positioned to pass the first part **182** once per revolution of the arm **128**. In some embodiments, the first part **182** may be coupled to the housing **118** near the rotational path of the arm **128**, and the second part **184** may be coupled to an end of the arm.

[0041] Any suitable type of position sensor may be used in the position sensor assembly **180**. One example of a position sensor assembly **180** may include a position sensor, such as a hall effect sensor, as the first part **182** and a sensor target, such as a magnet, as the second part **184**. In general, an active or electrically-powered part of the position sensor assembly **180** may be coupled to the stationary assembly **126** and a passive or non-powered part of the assembly may be coupled to the rotating assembly **122**.

[0042] In general, the arm **128** rotates in one direction about the axis **150**. In the illustration, arrows are used to show the arm **128** rotating in a clockwise direction. The position sensor assembly **180** may be used to detect when the arm **128** has made one complete revolution around the axis **150**.

[0043] As perhaps best seen in **FIG. 5**, the control system **138** may include a controller **200** operably coupled to the position sensor assembly **180**, the motor **124**, the one or more actuators **132**, and a user interface **190**. In particular, the position sensor assembly **180** and the user interface **190** may be operably coupled to an input interface **202** of the controller **200**, and the motor **124** and the one or more actuators **132** may be operably coupled to the output interface **204** of the controller **200**. The controller **200** may include a processor **206** and a memory **208**. The processor **206** may be operably

coupled to the input interface **202**, the output interface **204**, and the memory **208**. The input interface **202** and the output interface **204** may be physically different interfaces or a single interface capable of input and output functionalities. The input interface **202** and the output interface **204** may use any suitable wired or wireless connection to operably connect the controller to the respective components.

[0044] A processor **206** of the controller **200** may receive an indication of the arm location from the input interface **202** and may determine a rotational speed of the arm based on the indication. Any suitable technique for determining the rotational speed of the arm known to one of ordinary skill in the art having the benefit of this disclosure may be used. In one or more embodiments described herein, the processor **206** may be configured to run one or more timers while the arm **128** is rotated by the motor **124**. The processor **206** may start a timer when receiving a first indication from the position sensor assembly **180** that one segment of the arm **128** has passed a particular location. The processor **206** may stop the timer when receiving a second indication from the position sensor assembly **180** that the same segment of the arm **128** has passed the particular location again. The value of the timer, or the duration between the start time and the stop time of the timer, can be used to correspond to one revolution of the arm **128** and used to determine a rotational speed of the arm **128**, such as a number of revolutions per minute (RPM).

[0045] The rotational speed of the arm may be stored in the memory **208**. The rotational speed is used by the processor **206** to determine parameters related to pulse delivery cleaning, for example, to determine a pattern of pulses.

[0046] A predetermined pattern of pulses may be used so that the pulse delivery cleaning system **120** can clean all filter bags **104** within a desired full clean time. The predetermined pattern may correspond to rotating the arm **128** past a predetermined number of one or more radial spokes **152** between pulses. In some embodiments, the predetermined number of spokes **152** is greater than one, and a full clean cycle of the filter bags **104** corresponds to more than one revolution of the arm. For example, as can be seen with reference to **FIG. 4**, the predetermined pattern skips three spokes **152**

between pulses. The subset **171** of spokes **152** having diagonal line shading represents the spokes that may receive a pressurized pulse **140** during a first revolution of the arm **128**.

[0047] In some embodiments, the processor **206** may determine a pulse interval for pulse delivery cleaning. As used herein, the term “pulse interval” refers to a time duration between subsequent deliveries of pulses during rotation of the arm **128**. The pulse interval may be determined based on a desired number of spokes passed or skipped between pulses and the rotational speed of the arm **128**. For example, predetermined pattern of pulses may define a pulse interval that corresponds to rotation past four of the spokes **152**, which may also be described an arc length of four spokes, or a pulse interval that skips three spokes between pulses. As can be seen in **FIG. 4**, for example, rotation past four spokes **152** is equal to an arc length **170**. The pulse interval may be determined based on dividing the arc length **170** by the rotational speed of the arm **128**.

[0048] In some embodiments, the predetermined number of radial spokes **152** passed during one pulse interval is divisible into the total number of spokes. In other words, the total number of spokes **152** may be an integer multiple of the predetermined number of radial spokes passed during one pulse interval.

[0049] After the first revolution of the arm **128**, which may be detected using the position sensor assembly **180**, the predetermined pattern of pulses may jog, or shift, the subsequent pulses. As can be seen in **FIG. 4**, the subset **173** of spokes **152** having “W”-pattern line shading may represent the spokes that may receive a pressurized pulse **140** as the arm **128** makes a second revolution. The subsequent pulses may be jogged after each revolution of the arm **128**.

[0050] Using a jogging functionality with the pulse interval with may facilitate even coverage of the spokes **152**. The processor **206** may also determine a jog interval for pulse delivery cleaning. As used herein, the term “jog interval” refers to a duration between successive deliveries of pulses that is different than the pulse interval, which may be used at the beginning of one or more revolutions of the arm **128**. The jog interval may be determined based on a desired number of spokes shifted each revolution of the arm **128** and the rotational speed of the arm **128**. For example, the predetermine pattern of pulses may define a jog interval that corresponds to rotation past three of the spokes

152, which may also be described an arc length of three spokes, or a pulse interval that skips two spokes between pulses. As can be seen in **FIG. 4**, for example, rotation past three spokes **152** is equal to an arc length **172**. The jog interval may be determined based on dividing the arc length **172** by the rotational speed of the arm **128**.

[0051] In the illustrated embodiment, the arc length **172** corresponding to the jog interval is shorter than the arc length **170** corresponding to the pulse interval. Accordingly, the corresponding jog interval may be proportionally shorter in time than the corresponding pulse interval. For example, the jog interval may be configured to provide a subsequent pulse command one spoke **152** earlier than the pulse interval. In other embodiments, the jog interval may be longer than the pulse interval. One or both of the pulse interval and the jog interval may be stored into the memory **208**.

[0052] In one or more embodiments described herein, the processor **206** may be configured to provide a set of pulse commands to the one or more actuators **132** to provide a set of pulses over one or more revolutions of the arm **128**. A pulse command may be a voltage excitation pulse provided from the controller **200** to the one or more actuators **132**. In one example, each pulse command has a 100-millisecond duration. The processor **206** may also be configured to determine a jog interval between the set of pulse commands and a subsequent set of pulse commands based on a measured rotational speed of the arm **128**. Further, the processor **206** may provide, after waiting one jog interval, the subsequent set of pulse commands to the one or more actuators **132** to provide a subsequent set of pulses over one or more subsequent revolutions of the arm **128**. The pulse commands or the subsequent pulse commands may be spaced by one pulse interval.

[0053] The processor **206** may be configured to provide each of the pulse commands when at least one of the one or more outlets **160** is centered over a corresponding hole **108** of the tube sheet **102**, which may ensure an effective “dead center” backflush pulse to the filter bags **104**. In some embodiments, the first part **182** of the position sensor assembly **180** may be aligned to a center of one of the spokes **152**, and the second part **184** of the position sensor assembly may be aligned to the outlets **160**. The predetermined pattern of pulses may be initiated based on activation of the position sensor assembly **180**. In other embodiments, the position sensor assembly **180** may not be aligned to one

of the spokes **152**, but the center of the subsequent spoke **152** may be calculated based on a known distance from the first part **182** of the position sensor assembly **180** to the center of the subsequent spoke and the measured rotational speed of the arm **128**.

[0054] The processor **206** may be configured to measure the rotational speed of the arm **128** after each of a first predetermined number of one or more revolutions of the arm. In some embodiments, the rotational speed of the arm **128** is measured, or determined, after each revolution of the arm. In other words, the first predetermined number may be equal to one.

[0055] The processor **206** may also be configured to wait one jog interval after each of a second predetermined number of one or more revolutions of the arm **128**. In some embodiments, the processor **206** is configured to wait one jog interval after each revolution of the arm **128**. In other words, the second predetermined number may be equal to one.

[0056] The user interface **190** of the control system **138** may be configured to accept user input or to provide information to the user. Any suitable type of user interface may be used, such as a keyboard, a button, a knob, a graphical user interface and display (e.g., including touchscreen), microphone, or speaker. A user may provide user input to the controller **200** through the user interface **190**. In some embodiments, the user input may indicate a tube sheet hole configuration, such as the number of spokes **152** in the tube sheet **102**. In some embodiments, a pulse interval or jog interval may be determined based on user input indicating the tube sheet hole configuration and the measured rotational speed of the arm using the position sensor assembly **180**. User input may also indicate the preset rotational speed of the motor, which may be used to determine an initial pulse interval or jog interval. User input may also indicate a desired full clean time, which may be used to determine the pulse interval or jog interval.

[0057] Further, the controller **200** may determine whether the measured location of the arm **128** at a given time indicates that the rotating assembly **122** requires maintenance and can provide an alarm to the user interface **190**. In one example, a maintenance-type alarm may be provided to the user interface **190**, which may be an audio or visual alert, when the time between activations of the position sensor assembly **180** exceeds a

threshold time, which may indicate that the rotating assembly **122** is moving at only a portion of its intended speed. For example, an alarm may be provided when one rotation takes 2 minutes instead of only 1 minute, indicating the rotating assembly **122** is moving at half of its intended speed.

[0058] In one or more embodiments, a proximity sensor is used in the position sensor assembly **180** to measure the arm location for calculating the rotational speed. With this information, pulse logic can be programmed into a programmable logic controller (PLC) used in the control system **138** and pulse commands can be sent to a solenoid as the actuator **132** to control pulse timing to fire the diaphragm valve, such that a pulse of backflushed air is directed at the center of each hole **108** in one spoke **152** of the tube sheet **102**. In addition, sequence adjustments can be programmed to provide a predetermined pattern of pulses having a jog pattern every predetermined number of pulses to facilitate coverage of all holes **108** in the tube sheet **102** within a full clean time. Without jogging, a repeating or periodic pulse pattern can develop that leaves some spokes **152** of the tube sheet **102** un-pulsed or unevenly pulsed within a full clean time. Sequence adjustments made to change the pulse interval time may directly influence the pressure in the tank **130** achieved during the refilling operation between pulses, for example, to facilitate adjusting tank pressurization while still pulsing on the “dead center” of the tube sheet holes **108**. Lastly, by using the position sensor assembly **180** to calibrate and adjust the pulse interval time during operation, no “fine tuning” may be needed during installation of the filter system **100**.

[0059] One or more of the components, such as controllers, processors, or sensors, described herein may include a processor, such as a central processing unit (CPU), computer, logic array, or other device capable of directing data coming into or out of the controller. The controller may include one or more computing devices having memory, processing, and communication hardware. The controller may include circuitry used to couple various components of the controller together or with other components operably coupled to the controller. The functions of the controller may be performed by hardware and/or as computer instructions on a non-transient computer readable storage medium.

[0060] The processor of the controller may include any one or more of a microprocessor, a microcontroller, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), and/or equivalent discrete or integrated logic circuitry. In some examples, the processor may include multiple components, such as any combination of one or more microprocessors, one or more controllers, one or more DSPs, one or more ASICs, and/or one or more FPGAs, as well as other discrete or integrated logic circuitry. The functions attributed to the controller or processor herein may be embodied as software, firmware, hardware, or any combination thereof. While described herein as a processor-based system, an alternative controller could utilize other components such as relays and timers to achieve the desired results, either alone or in combination with a microprocessor-based system.

[0061] In one or more embodiments, the exemplary systems, methods, and interfaces may be implemented using one or more computer programs using a computing apparatus, which may include one or more processors and/or memory. Program code and/or logic described herein may be applied to input data/information to perform functionality described herein and generate desired output data/information. The output data/information may be applied as an input to one or more other devices and/or methods as described herein or as would be applied in a known fashion. In view of the above, it will be readily apparent that the controller functionality as described herein may be implemented in any manner known to one skilled in the art.

[0062] **FIG. 6** shows one example of a method **300** for operating a pulse delivery cleaning system, such as pulse delivery cleaning system **120**, using a predetermined pattern of pulses. The method **300** may include rotating the arm until the position sensor assembly, or position sensor, activates twice in process **302**. In general, the arm may be rotated more than 360 degrees but less than 720 degrees. A timer may be used to determine the time between activations of the position sensor. The method **300** may include determining a rotational speed of the arm in process **304**, for example, based on the time between activations of the position sensor. In this case, the jog interval may be calculated as three-fourths of the pulse interval or 7.5 seconds.

[0063] The method **300** may include calculating a pulse interval and a jog interval based on the rotational speed in process **306**. For example, the pulse interval may be determined based on a desired full clean time, the number of spokes in the tube sheet, and the rotational speed of the arm. For example, if the full clean time is four minutes and the tube sheet has twenty-four spokes, then six spokes need to be cleaned every minute to provide a full clean cycle within the full clean time. If the arm rotates at 1 RPM, then six spokes need to be cleaned per revolution at one pulse every 10 seconds, and the full clean cycle corresponds to four revolutions of the arm. The pulse interval may be calculated as 10 seconds, which should correspond to arm rotation past four spokes. The jog interval may be determined based on a desired shift in spokes, the pulse interval, and the number of spokes in the tube sheet. Using the same example, a desired shift in spokes may advance subsequent pulses by one spoke. Knowing that the pulse interval corresponds to arm rotation past four spokes, the jog interval should correspond to arm rotation past three spokes.

[0064] The method **300** may include waiting one pulse interval in process **308** and then providing a pulse in process **310** after the pulse interval expires. The method **300** may determine whether the position sensor has been activated again in process **312**. If the position sensor has not been activated again, the method **300** may return to continue waiting one pulse interval in process **308** and providing a pulse in process **310**.

[0065] Once the position sensor has been activated, the method **300** may redetermine the rotational speed of the arm in process **314**. The method **300** may also determine whether the rotational speed of the arm has changed in process **316**. Small changes in rotational speed can occur, for example, due to gear wear, small changes to alternating current (AC) frequencies, and changes that affect power to the motor. In response to the rotational speed being unchanged, the method **300** may wait one jog interval in process **320** and provide a pulse in process **322**. In response to the rotational speed being changed, the method **300** may include recalculating the pulse interval and the jog interval in process **318**. Using the example above, even a one-percent error, or change, from a preset rotational speed of 1 RPM to an actual rotational speed of 1.01 RPM may cause the pulse delivery system to miss a spoke, especially in systems with a large number of

spokes. Recalculating the pulse interval and the jog interval based on the rotational speed, for example, in process **318**, may prevent such misses.

[0066] The method **300** may then continue to wait one jog interval in process **320** and provide a pulse in process **322**. In other embodiments, the method **300** may not need to decide whether the rotational speed of the arm has changed in process **316** and may instead recalculate the pulse interval and the jog interval in process **318** once every revolution in response to an activation, or triggering, of the position sensor.

[0067] After providing the pulse in process **322**, the method **300** may return to waiting one pulse interval in process **308** and providing a pulse in process **310**. The method **300** may continue to loop in this manner until the motor is turned off.

ILLUSTRATIVE EMBODIMENTS

[0068] While the present disclosure is not so limited, an appreciation of various aspects of the disclosure will be gained through a discussion of the specific illustrative embodiments provided below. Various modifications of the illustrative embodiments, as well as additional embodiments of the disclosure, will become apparent herein.

[0069] In illustrative embodiment A1, a system includes a stationary assembly having a tube sheet defining a plurality of holes in fluid communication with a plurality of filter bags and further having one or more actuators each configured to release pressurized air in response to a pulse command. The system also includes a rotating assembly having an arm defining one or more outlets positioned along a length of the arm. The one or more outlets are configured to provide pressurized air from an air source toward the tube sheet in response to the one or more actuators receiving a pulse command. The system also includes a motor operably coupled to the stationary assembly and the rotating assembly configured to rotate the arm about an axis at a preset rotational speed. The system also includes a controller operably coupled to the motor and the one or more actuators. The controller includes a processor configured to: provide a set of pulse commands to the one or more actuators to provide a set of pulses over one or more revolutions of the arm, determine a jog interval between the set of pulse commands and a subsequent set of pulse commands based on a measured rotational speed of the arm, and provide, after waiting

one jog interval, the subsequent set of pulse commands to the one or more actuators to provide a subsequent set of pulses over one or more subsequent revolutions of the arm.

[0070] In illustrative embodiment A2, a system includes a system according to any A embodiment, wherein the processor is further configured to provide each of the commands when at least one of the one or more outlets is centered over a corresponding hole of the plurality of holes in the tube sheet.

[0071] In illustrative embodiment A3, a system includes a system according to any A embodiment, wherein the processor is further configured to determine the measured rotational speed of the arm after each of a first predetermined number of one or more revolutions of the arm.

[0072] In illustrative embodiment A4, a system includes a system according to any A embodiment, wherein the processor is further configured to wait one jog interval after each of a second predetermined number of one or more revolutions of the arm.

[0073] In illustrative embodiment A5, a system includes a system according to embodiment A3 or A4, wherein the first or second predetermined number of one or more revolutions is one revolution.

[0074] In illustrative embodiment A6, a system includes a system according to any A embodiment, further including a position sensor assembly coupled to the stationary assembly to provide measurements related to rotation of the arm.

[0075] In illustrative embodiment A7, a system includes a system according to embodiment A6, wherein a first part of the position sensor assembly is coupled to the stationary assembly and a second part of the position sensor assembly is coupled to the rotating assembly.

[0076] In illustrative embodiment A8, a system includes a system according to any A embodiment, wherein the processor is further configured to provide the subsequent set of pulse commands spaced by a pulse interval between the pulse commands.

[0077] In illustrative embodiment A9, a system includes a system according to embodiment A8, wherein the jog interval is shorter than the pulse interval.

[0078] In illustrative embodiment A10, a system includes a system according to embodiment A8 or A9, wherein the plurality of holes of the tube sheet are arranged into radial spokes and the pulse interval corresponds to rotation of the arm past a predetermined number of radial spokes.

[0079] In illustrative embodiment A11, a system includes a system according to embodiment A10, wherein the jog interval is configured to provide a subsequent pulse command one spoke earlier than the pulse interval.

[0080] In illustrative embodiment A12, a system includes a system according to embodiment A10 or A11, wherein the predetermined number of radial spokes is greater than one spoke.

[0081] In illustrative embodiment A13, a system includes a system according to any of embodiments A10-A12, wherein a total number of radial spokes is an integer multiple of the predetermined number of radial spokes passed during the pulse interval.

[0082] In illustrative embodiment A14, a system includes a system according to any A embodiment, wherein the plurality of holes in the tube sheet are arranged into concentric rings. The arm has a first segment defining a first set of the one or more outlets and a second segment defining a second set of the one or more outlets. The first set of the outlets are aligned to different concentric rings than the second set of the outlets.

[0083] In illustrative embodiment A15, a system includes a system according to embodiment A14, wherein one of the concentric rings has fewer of the plurality of holes in the tube sheet than another one of the concentric rings further from the axis.

[0085] In illustrative embodiment B1, an apparatus includes an input interface, an output interface, a memory, and a processor operably coupled to the input interface, the output interface, and the memory. The processor is configured to determine a rotational speed of an arm based on measurements from a position sensor assembly using the input interface. The arm defining one or more outlets are configured to release pressurized air in response to one or more actuators receiving a pulse command. The processor is also configured to determine a pulse interval and a jog interval based on the rotational speed of the arm. The

pulse interval defines an interval between pulse commands in one set of pulse commands. The jog interval defines an interval between a set of pulse commands and a subsequent set of pulse commands. The processor is also configured to store the pulse interval and the jog interval into the memory. The processor is also configured to provide the subsequent set of pulse commands based on the pulse interval and the jog interval to the one or more actuators using the output interface to release the subsequent set of pulses of pressurized air through the one or more outlets.

[0086] In illustrative embodiment C1, a method includes revolving an arm about an axis. The arm defining one or more outlets positioned along a length of the arm. The one or more outlets are configured to direct pressurized air from an air source toward a tube sheet. The tube sheet defines a plurality of holes in fluid communication with a plurality of filter bags. The method also includes releasing a set of pulses of pressurized air from the one or more outlets over one or more revolutions of the arm. The method also includes determining a jog interval between the set of pulses and a subsequent set of pulses of pressurized air based on a measured rotational speed of the arm. The method also includes releasing, after waiting one jog interval, the subsequent set pulses from the one or more outlets over one or more subsequent revolutions of the arm.

[0087] In illustrative embodiment C2, a method includes a method according to any C embodiment, further including revolving the arm at least one revolution before determining the measured rotational speed of the arm.

[0088] In illustrative embodiment C3, a method includes a method according to any C embodiment, further including determining a pulse interval between pulses in the subsequent set of pulses based on user input indicating a tube sheet hole configuration and the measured rotational speed of the arm.

[0089] In illustrative embodiment C4, a method includes a method according to any C embodiment, wherein a full clean cycle of the plurality of filter bags corresponds to more than one revolution of the arm.

[0090] Thus, various embodiments of the PULSE DELIVERY CLEANING SYSTEMS AND METHODS are disclosed. Although reference is made herein to the accompanying set of drawings that form part of this disclosure, one of at least ordinary

skill in the art will appreciate that various adaptations and modifications of the embodiments described herein are within, or do not depart from, the scope of this disclosure. For example, aspects of the embodiments described herein may be combined in a variety of ways with each other. Therefore, it is to be understood that, within the scope of the appended claims, the claimed invention may be practiced other than as explicitly described herein.

[0091] All scientific and technical terms used herein have meanings commonly used in the art unless otherwise specified. The definitions provided herein are to facilitate understanding of certain terms used frequently herein and are not meant to limit the scope of the present disclosure.

[0092] Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims may be understood as being modified either by the term “exactly” or “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein or, for example, within typical ranges of experimental error.

[0093] The recitation of numerical ranges by endpoints includes all numbers subsumed within that range (e.g. 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5) and any range within that range. Herein, the terms “up to” or “no greater than” a number (e.g., up to 50) includes the number (e.g., 50), and the term “no less than” a number (e.g., no less than 5) includes the number (e.g., 5).

[0094] The terms “coupled” or “connected” refer to elements being attached to each other either directly (in direct contact with each other) or indirectly (having one or more elements between and attaching the two elements). Either term may be modified by “operatively” and “operably,” which may be used interchangeably, to describe that the coupling or connection is configured to allow the components to interact to carry out functionality.

[0095] As used herein, the term “configured to” may be used interchangeably with the terms “adapted to” or “structured to” unless the content of this disclosure clearly dictates otherwise.

[0096] Th singular forms “a,” “an,” and “the” encompass embodiments having plural referents unless its context clearly dictates otherwise.

[0097] The phrases “at least one of,” “comprises at least one of,” and “one or more of” followed by a list refers to any one of the items in the list and any combination of two or more items in the list.

[0098] As used herein, “have,” “having,” “include,” “including,” “comprise,” “comprising” or the like are used in their open-ended sense, and generally mean “including, but not limited to.” It will be understood that “consisting essentially of,” “consisting of,” and the like are subsumed in “comprising,” and the like.

CLAIMS

What is claimed is:

1. A system comprising:
 - a stationary assembly comprising a tube sheet defining a plurality of holes in fluid communication with a plurality of filter bags and further comprising one or more actuators each configured to release pressurized air in response to a pulse command;
 - a rotating assembly comprising an arm defining one or more outlets positioned along a length of the arm, the one or more outlets configured to provide pressurized air from an air source toward the tube sheet in response to the one or more actuators receiving a pulse command;
 - a motor operably coupled to the stationary assembly and the rotating assembly configured to rotate the arm about an axis at a preset rotational speed; and
 - a controller operably coupled to the motor and the one or more actuators, the controller comprising a processor configured to:
 - provide a set of pulse commands to the one or more actuators to provide a set of pulses over one or more revolutions of the arm,
 - determine a jog interval between the set of pulse commands and a subsequent set of pulse commands based on a measured rotational speed of the arm, and
 - provide, after waiting one jog interval, the subsequent set of pulse commands to the one or more actuators to provide a subsequent set of pulses over one or more subsequent revolutions of the arm.
2. The system according to any preceding claim, wherein the processor is further configured to provide each of the commands when at least one of the one or more outlets is centered over a corresponding hole of the plurality of holes in the tube sheet.

3. The system according to any preceding claim, wherein the processor is further configured to determine the measured rotational speed of the arm after each of a first predetermined number of one or more revolutions of the arm.
4. The system according to any preceding claim, wherein the processor is further configured to wait one jog interval after each of a second predetermined number of one or more revolutions of the arm.
5. The system according to claim 3 or 4, wherein the first or second predetermined number of one or more revolutions is one revolution.
6. The system according to any preceding claim, further comprising a position sensor assembly coupled to the stationary assembly to provide measurements related to rotation of the arm.
7. The system according to claim 6, wherein a first part of the position sensor assembly is coupled to the stationary assembly and a second part of the position sensor assembly is coupled to the rotating assembly.
8. The system according to any preceding claim, wherein the processor is further configured to provide the subsequent set of pulse commands spaced by a pulse interval between the pulse commands.
9. The system according to claim 8, wherein the jog interval is shorter than the pulse interval.
10. The system according to claim 8 or 9, wherein the plurality of holes of the tube sheet are arranged into radial spokes and the pulse interval corresponds to rotation of the arm past a predetermined number of radial spokes.

11. The system according to claim 10, wherein the jog interval is configured to provide a subsequent pulse command one spoke earlier than the pulse interval.
12. The system according to claim 10 or 11, wherein the predetermined number of radial spokes is greater than one spoke.
13. The system according to any one of claims 10-12, wherein a total number of radial spokes is an integer multiple of the predetermined number of radial spokes passed during the pulse interval.
14. The system according to any preceding claim, wherein the plurality of holes in the tube sheet are arranged into concentric rings, wherein the arm comprises a first segment defining a first set of the one or more outlets and a second segment defining a second set of the one or more outlets, wherein the first set of the outlets are aligned to different concentric rings than the second set of the outlets.
15. The system according to claim 14, wherein one of the concentric rings has fewer of the plurality of holes in the tube sheet than another one of the concentric rings further from the axis.
16. An apparatus comprising:
 - an input interface;
 - an output interface;
 - a memory; and
 - a processor operably coupled to the input interface, the output interface, and the memory, the processor configured to:

determine a rotational speed of an arm based on measurements from a position sensor assembly using the input interface, the arm defining one or more outlets configured to release pressurized air in response to one or more actuators receiving a pulse command;

determine a pulse interval and a jog interval based on the rotational speed of the arm, the pulse interval defining an interval between pulse commands in one set of pulse commands, the jog interval defining an interval between a set of pulse commands and a subsequent set of pulse commands,

store the pulse interval and the jog interval into the memory, and

provide the subsequent set of pulse commands based on the pulse interval and the jog interval to the one or more actuators using the output interface to release the subsequent set of pulses of pressurized air through the one or more outlets.

17. A method comprising:

revolving an arm about an axis, the arm defining one or more outlets positioned along a length of the arm, the one or more outlets configured to direct pressurized air from an air source toward a tube sheet, the tube sheet defining a plurality of holes in fluid communication with a plurality of filter bags;

releasing a set of pulses of pressurized air from the one or more outlets over one or more revolutions of the arm;

determining a jog interval between the set of pulses and a subsequent set of pulses of pressurized air based on a measured rotational speed of the arm; and

releasing, after waiting one jog interval, the subsequent set pulses from the one or more outlets over one or more subsequent revolutions of the arm.

18. The method according to claim 17, further comprising revolving the arm at least one revolution before determining the measured rotational speed of the arm.

19. The method according to claim 17 or 18, further comprising determining a pulse interval between pulses in the subsequent set of pulses based on user input indicating a tube sheet hole configuration and the measured rotational speed of the arm.

20. The method according to any one of claims 17-19, wherein a full clean cycle of the plurality of filter bags corresponds to more than one revolution of the arm.

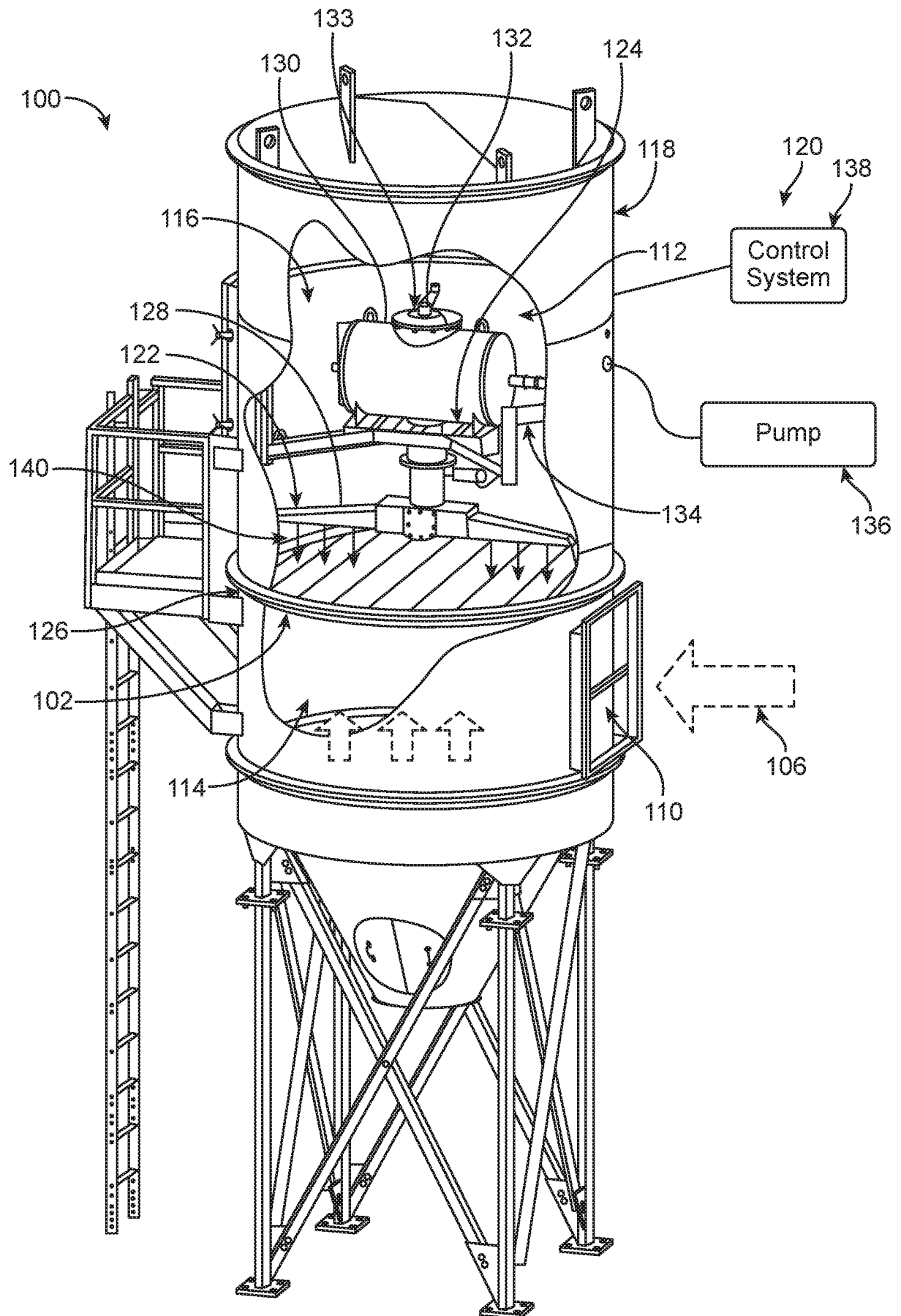


FIG. 1

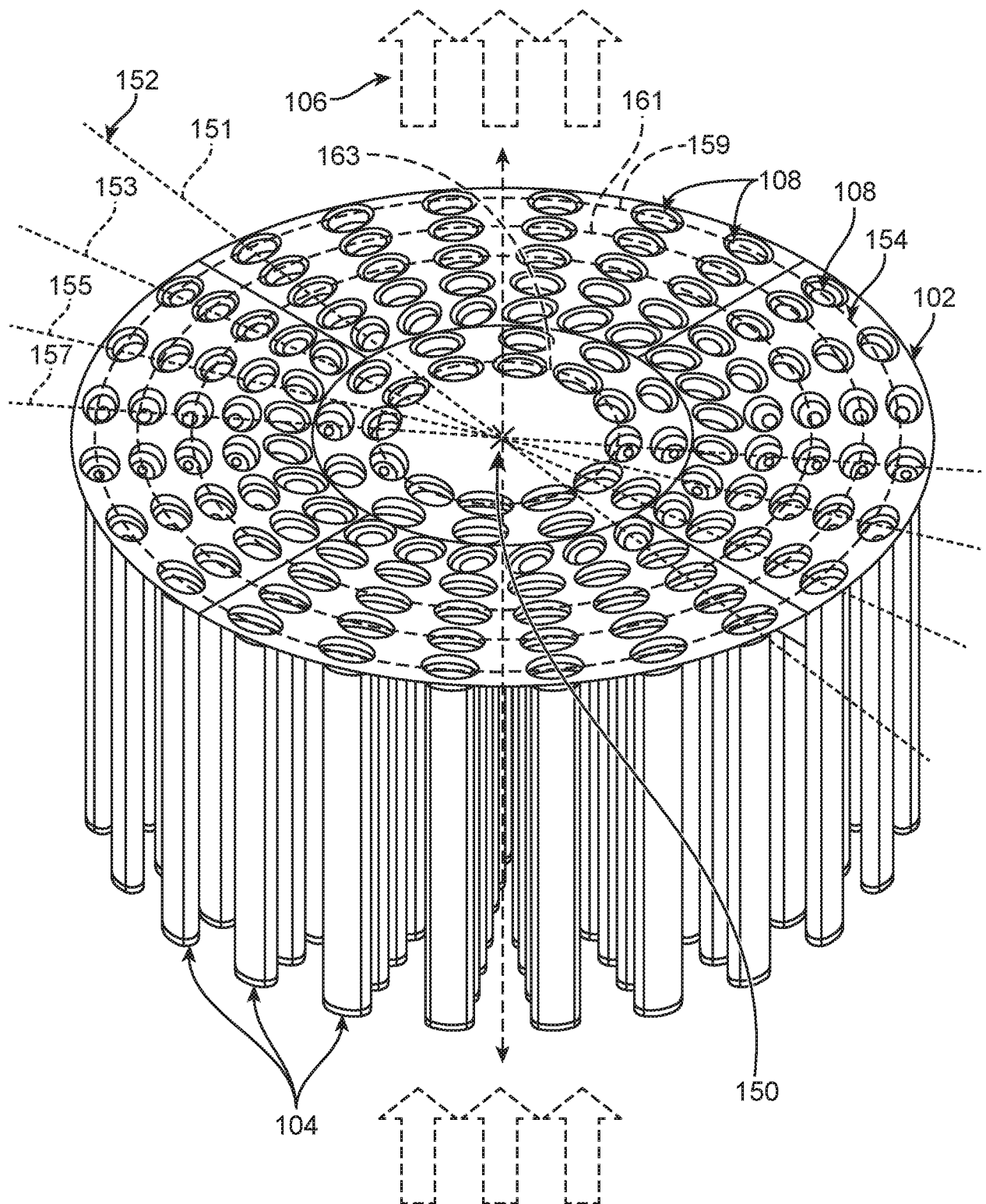


FIG. 2.

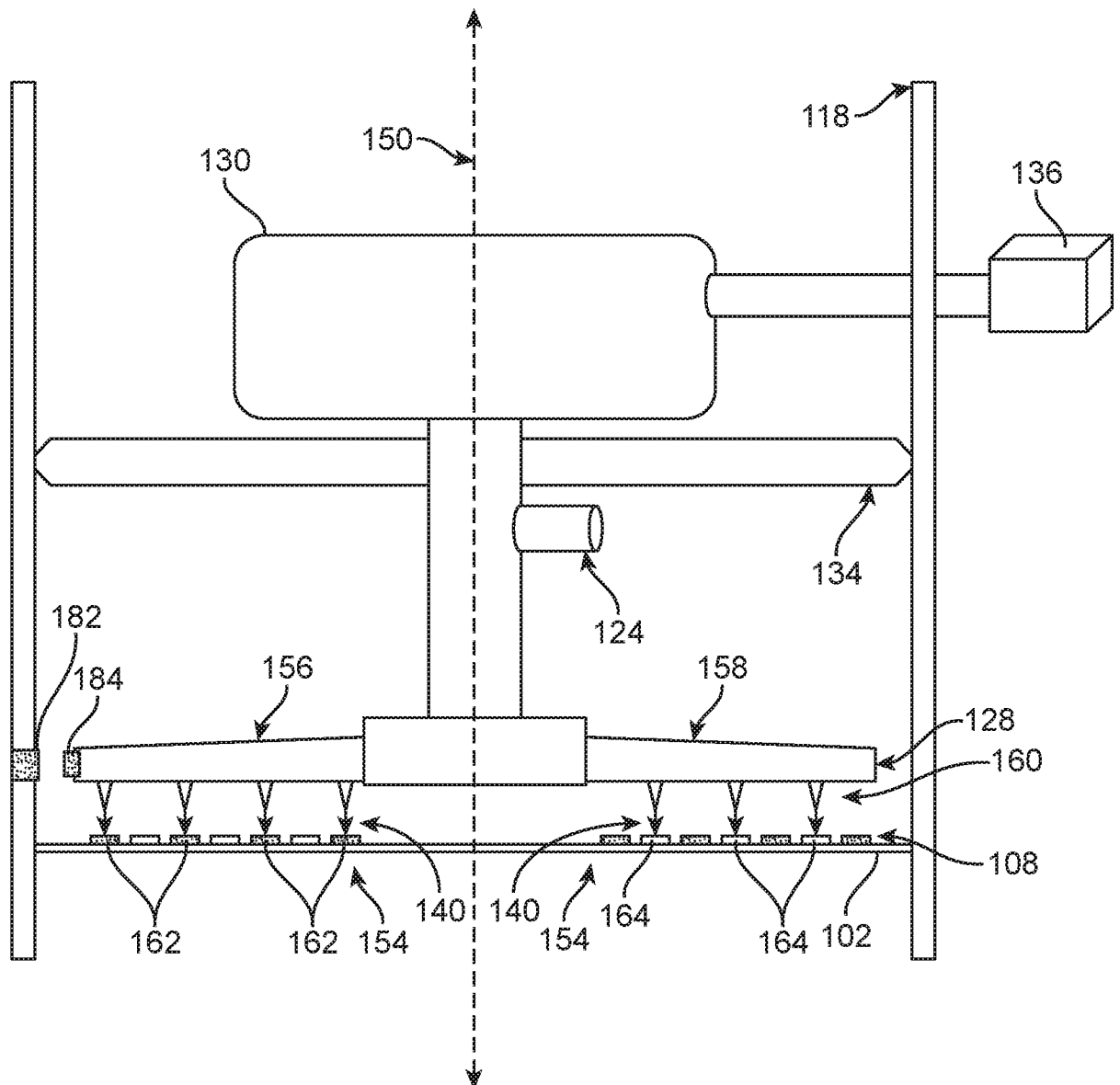


FIG. 3

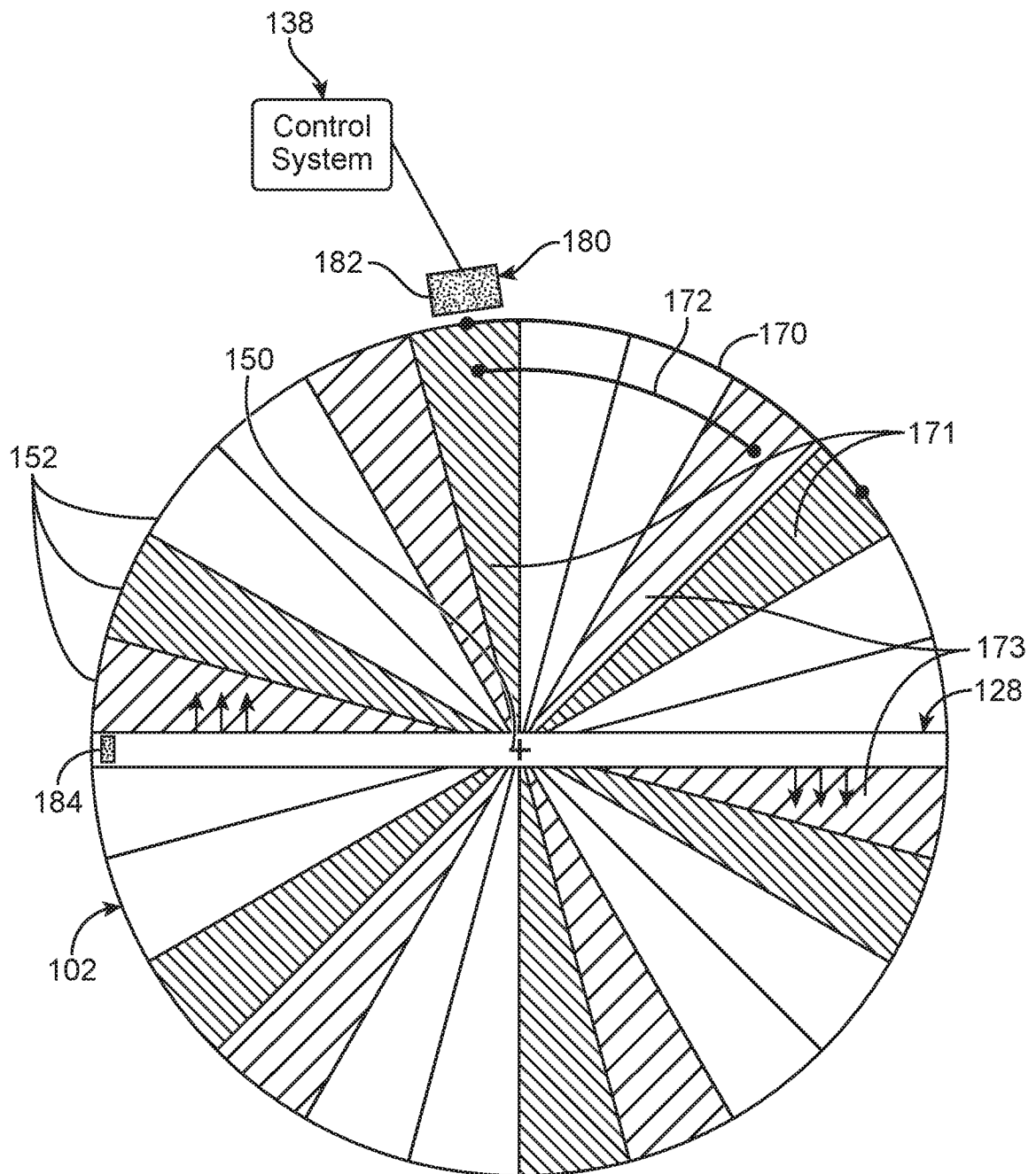


FIG. 4

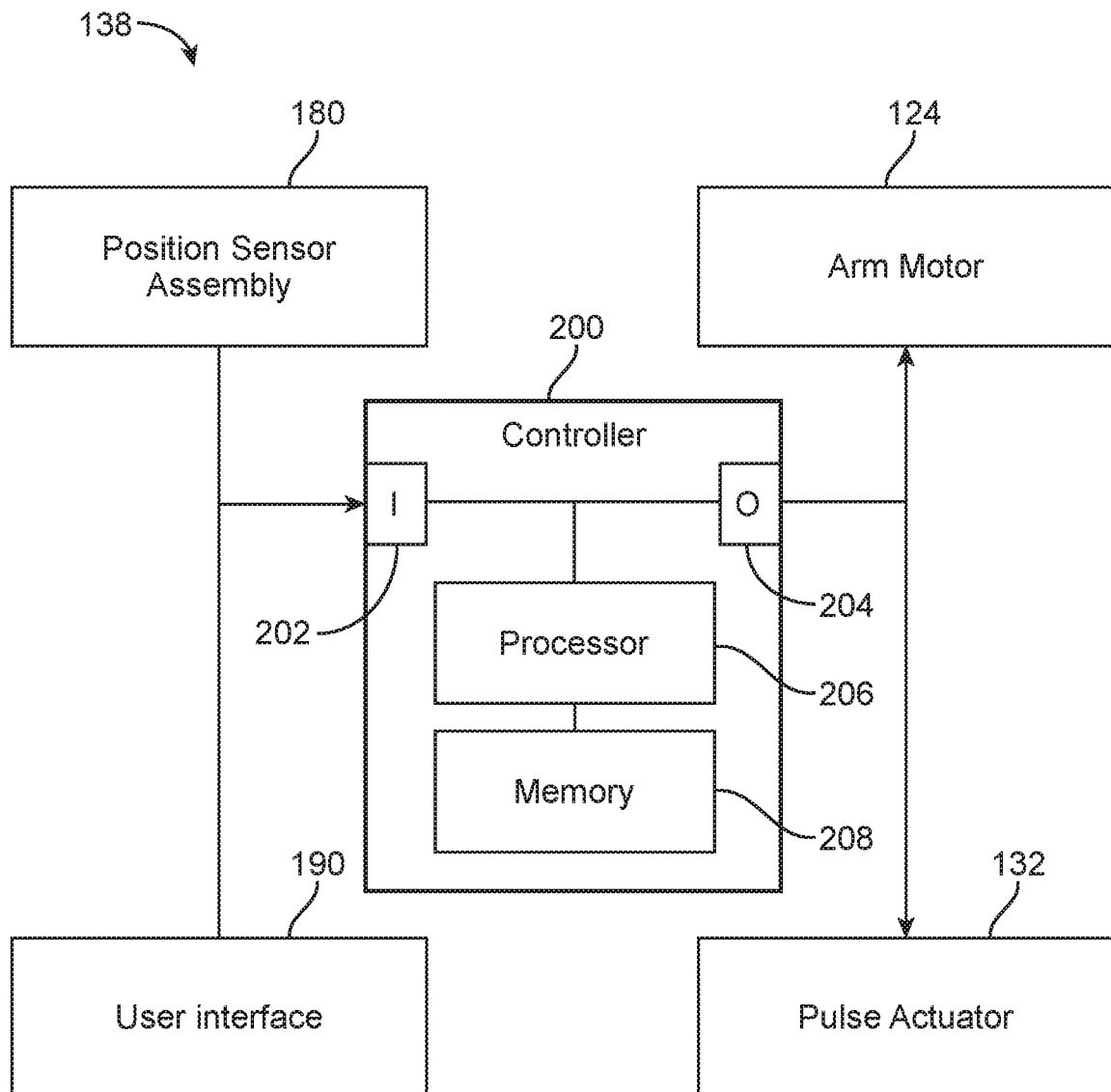


FIG. 5

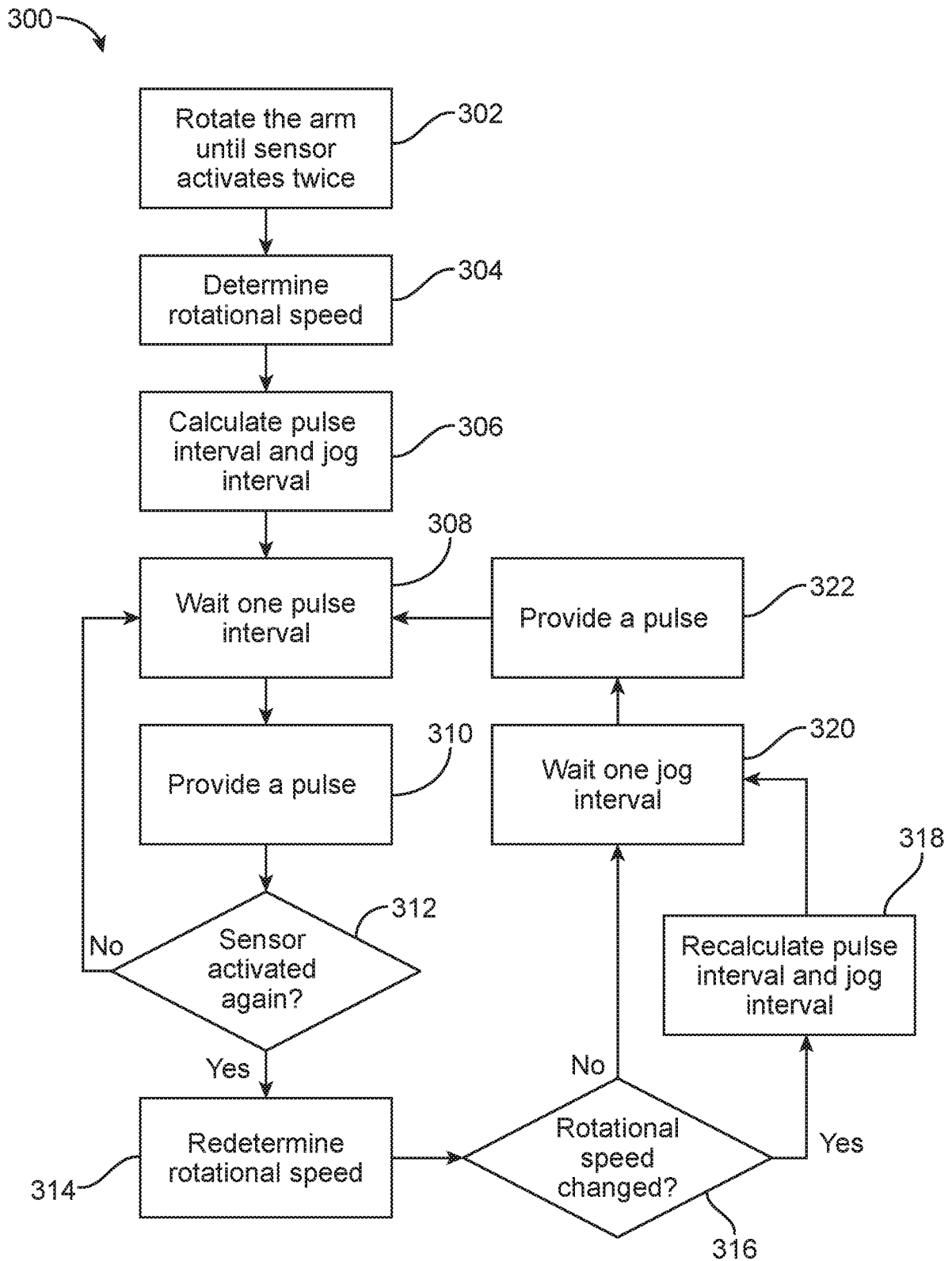


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/023502

A. CLASSIFICATION OF SUBJECT MATTER

INV. B01D46/02 B01D46/04 B01D46/24 B01D29/11
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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 525 417 A1 (PNEUMAFIL CORP [US]) 3 February 1993 (1993-02-03)	1-3,5-8, 14-20
A	column 9, line 43 - column 13, line 52; figures 1,3,6	4,9-13
A	----- US 4 600 415 A (BARTON WILLIAM J [US]) 15 July 1986 (1986-07-15)	1-20
A	----- EP 1 628 737 A1 (LEE CHANG UN [KR]) 1 March 2006 (2006-03-01)	1-20
	paragraph [0045] - paragraph [0046]; figures 10-12 -----	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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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

8 June 2020

Date of mailing of the international search report

23/06/2020

Name and mailing address of the ISA/

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Blumenberg, Claus

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2020/023502

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0525417	A1	03-02-1993	AT 128379 T 15-10-1995
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