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- (71) Applicant (for all designated States except US): PNEUMATIC SCALE CORPORATION [US/US]; 10 Ascot Parkway, Cuyahoga Falls, Ohio 44223 (US).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): MARRO, T. David [US/US]; 26 Long Hill Road, Magnolia, Massachusetts 01930 (US).
- (74) Agent: PARMELEE, Christopher; 231 South Broadway, Medina, Ohio 44256 (US).

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(54) Title: A CENTRIFUGE SYSTEM AND METHOD

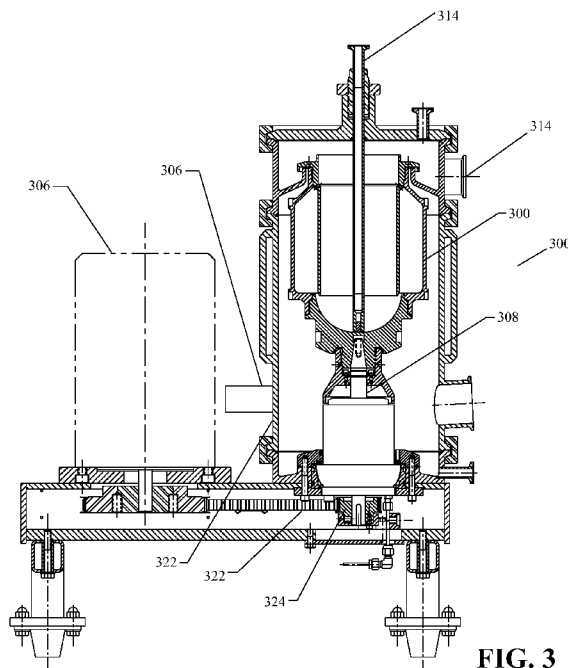


FIG. 3

(57) Abstract: A centrifuge may include a bowl operative to rotate with respect to a stationary portion. The centrifuge may include at least one vibration sensor operative to generate vibration data representative of vibrational movement of portions of the centrifuge. The processor may monitor the vibration data as the bowl is being filled with a fluid. The processor may cause a drive device to increase the rotational speed of the bowl responsive to determining from the vibration data that the bowl has becoming substantially filled with a fluid.



Title: A Centrifuge System and Method

BACKGROUND

Semi-continuous process centrifuges may operate by feeding a fluid comprising a
5 liquid-solid suspension into a rotating bowl, sedimenting solids, and discharging liquid
until the bowl is filled or is substantially filled to capacity with solids. Once the bowl is
filled to capacity with solids, bowl rotation is stopped and the solids are discharged from
the bowl. Thereafter, the next cycle in the process is initiated by again feeding the fluid
into the rotating bowl, sedimenting solids, discharging liquid, followed by discharging the
10 solids when the bowl is once again sufficiently filled.

Some types of semi-continuous centrifuges operate at relatively lower rotational
speeds while the bowl is being filled with fluid from an empty state to avoid excessive
vibrations (caused by the fluid sloshing around in the unfilled space of the bowl). In
some centrifuges (e.g., a ViaFuge manufactured by Pneumatic Scale Angelus), a user
15 visually monitors the centrifuge to determine when the bowl is filled with fluid, at which
point the user stops the feed pump and manually increases the rotational speed of the
filled bowl to correspond to the appropriate processing speed for the liquid-solid
suspension that is to be separated. Upon reaching the appropriate increased rotational
processing speed, the pumping of the fluid into the bowl is resumed. When the desired
20 amount of fluid has been processed, and/or the bowl is filled with a maximum level of
solids, the bowl rotation is stopped and the solids collected in the bowl are discharged.

In this system, a user visually determines when the bowl is filled with the fluid by
observing when liquid begins to overflow from a discharge port. The composition of the
overflowing liquid may be either feed suspension or liquid separated from the suspension,
25 which is called centrate. In other types of centrifuges (e.g., a UniFuge manufactured by
Pneumatic Scale Angelus), the centrifuge may employ automatic controls which optically
sense the fill level in the bowl, in order to automatically control when to stop the feed
pump and increase the rotational speed of the bowl.

Unfortunately for each of these examples, various circumstances may degrade the
30 ability of these systems to consistently determine when a bowl is filled with the fluid,
which can negatively affect the processing rate of the systems and/or cause carry-over of
feed solids into centrate. For example, manually operated systems are susceptible to

human error as to when liquid begins overflowing through the centrate discharge port. Also, automatic systems may be susceptible to the accumulation of small amounts of residual solids or foam in a sensing zone at which the presence of liquid is being detected optically. This effect can interfere with optical sensing of the actual fill level of the bowl. Further, the monitoring of liquid that has overflowed from the bowl into a discharge port (e.g., with a manual system or an automated system) can result in some contamination of the liquid exiting the discharge port with feed solids during each bowl filling cycle. Thus there is a need for improvement to existing centrifuge designs.

SUMMARY

The following is a brief summary of subject matter that is described in greater detail herein. This summary is not intended to be limiting as to the scope of the claims.

Described herein are various technologies relating to centrifuges which provide increased reliability and/or processing speeds. An example system may include a centrifuge having both a rotating portion (e.g., a spindle, shaft, bowl, etc.) and a non-rotating portion (centrifuge housing, shaft/spindle assembly housings, mounting brackets, etc.). The system may include at least one vibration sensor mounted to a non-rotating portion of the centrifuge. The vibration sensor for example may correspond to an accelerometer operative to output signals including vibration data representative of vibrational movement in one or more directions.

In this described example embodiment, the system may include at least one processor that is operatively configured (e.g., via software, firmware, hardware, electrical circuits/interfaces, etc.) to monitor the vibration data provided by the vibration sensor during at least the time periods before and while the bowl of the centrifuge is being filled with a feed fluid from a substantially empty state. The processor may also be operatively configured to determine responsive to the vibration data, when the level of vibration associated with the centrifuge is indicative of the bowl being substantially filled but not yet completely filled with the fluid. Responsive to this determination, the processor may be operatively configured to: cause a feed device such as a pump associated with the centrifuge to stop filling the bowl with the fluid; and cause a drive device such as a motor to increase the rotational speed of the bowl. Thereafter the processor may be operatively configured to cause further fluid to be pumped into the centrifuge.

Other aspects will be appreciated upon reading and understanding the attached figures and description.

5

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram of an example system that operates a centrifuge responsive to vibration data indicative of when a bowl is substantially filled with a fluid.

Fig. 2 is a cross-sectional view of an example embodiment of a centrifuge system.

Fig. 3 is a cross-sectional view of an alternative example embodiment of a
10 centrifuge system.

Fig. 4 is a graph of vibration data acquired via a vibration sensor mounted to a centrifuge while a bowl is being filled.

Fig. 5 is a flow diagram that illustrates an example methodology for operating a centrifuge responsive to vibration data indicative of when a bowl is substantially filled
15 with a fluid.

DETAILED DESCRIPTION

Various technologies pertaining to centrifuge systems will now be described with reference to the drawings, where like reference numerals represent like elements
20 throughout. In addition, several functional block diagrams of example systems are illustrated and described herein for purposes of explanation; however, it is to be understood that functionality that is described as being carried out by certain system components and devices may be performed by multiple components and devices. Similarly, for instance, a component/device may be configured to perform functionality
25 that is described as being carried out by multiple components/devices.

With reference to Figure 1, an example system 100 that facilitates use of centrifugal forces to process fluids is illustrated. Such processes may involve the centrifugal separation of particulate solids such as cells from a liquid such as a cell culture media. For example such a process may comprise receiving a fluid feed
30 comprising suspended cells from a bioreactor and separating the fluid into a cell concentrate portion and a centrate (liquid) portion. However, it is to be understood that in alternative embodiments the system may be employed with other fluid process

applications that involve separation of solid particles suspended in liquids. As used herein a fluid is defined as a flowable medium that may include separable components including a liquid and solids. Also, as used herein the term solids corresponds to a plurality of particles, cells, and/or any other non-liquid matter included in the fluid along
5 with one or more liquids.

In an example embodiment, the system may comprise at least one centrifuge 101. The centrifuge may include a stationary portion 102 (e.g., a housing, bracket, enclosure, or other non-rotating component) and a fluid receiving bowl 104 that is operative to rotate with respect to the stationary portion 102. The centrifuge may also include a drive device
10 106 that is operative to selectively control a rotational speed of the bowl. Such a drive device may include a motor that is operative to cause a spindle connected to the bowl to rotate at a plurality of different rotational speeds. Also, the drive device may include a belt that connects the motor to the spindle of the bowl. However, it is to be understood that in alternative embodiments, the drive device may have a motor configured in other
15 arrangements to facilitate rotation of the bowl (e.g., direct drive, via gears, a transmission, and/or any other type of devices which are operative to transfer rotational energy from a motor to the bowl).

In example embodiments, the system may include a feed device 110 operative to selectively cause a fluid to be fed into the bowl 104. Such a feed device may for example
20 include a pump, feed tubes, and/or one or more valves that are operative to direct fluid from a reservoir into the bowl.

In addition, an example embodiment may include at least one processor 112 that is in operative connection with the drive device 106 and feed device 110. The processor 112 may be incorporated into at least one of a computing system (e.g., such as a computer
25 or dedicated controller) and may be operatively configured (via software, firmware) to control the drive device, feed device, and other functions of the centrifuge. For example, the at least one processor may be operative to turn the drive device on or off. Also the at least one processor may be operative to cause the drive device to rotate the bowl at different processing speeds (e.g., a relatively lower first rotational speed and a relatively
30 higher second rotational speed). Further, the at least one processor may be operatively configured to control the operation of the feed device. For example, the at least one processor may be operative to turn on/off a pump and/or switch a valve between an open

and closed state to control when the feed device moves fluid into the bowl. In addition, the at least one processor may be operatively configured to cause the centrifuge to carry out other functions associated with the operation and monitoring of the centrifuge.

An example embodiment of the centrifuge may experience varying degrees of vibrations depending on the amount of fluid in the bowl and the rotational speed of the bowl. In order to avoid excessive vibrations which may damage the centrifuge and/or degrade the processing characteristics of the centrifuge, the at least one processor may be operatively configured to cause the drive device to rotate the bowl at the relatively lower first rotational speed while the bowl is being initially filled with fluid from a substantially empty state. For example, at the beginning of a fill cycle, the at least one processor may cause the drive device to begin rotating the bowl at the first rotational speed and cause the feed device to begin pumping fluid into the bowl. The at least one processor may then be operatively configured to detect when the bowl is substantially filled with the fluid (which may be less than completely filled), and in response to this detection, the at least one processor may both cause the feed device to stop pumping fluid into the bowl and cause the drive device to increase the rotational speed of the bowl to the relatively higher second rotational speed. The relatively higher second rotational speed may have a generally more efficient ability to separate portions of the fluid (e.g., solids from liquid such as cells from centrate), in a manner that minimizes the risk of solids contaminating liquid flowing out of a discharge port 114 of the centrifuge. After a predetermined amount of time after the bowl begins rotating at the relatively higher second rotational speed (where the risk of solid contamination of the discharged liquid is lower), the at least one processor may be operatively configured to cause the feed device to begin again pumping fluid into the bowl.

In this described example, as fluid is being continually pumped into the bowl, liquid separated out of the fluid via the operation of the centrifuge may continually overflow through the discharge port into a collection reservoir. Simultaneously with the flow of discharged liquids into the collection reservoir, solids in the fluid may continually collect in the bowl via the operation of the centrifuge. Once a required batch of fluid has been processed in this manner, or when the bowl is sufficiently filled with solids, the at least one processor may be operatively configured to cause the bowl to be emptied (e.g., via pumping the solids out of the bowl and into a further reservoir). Once the bowl is

emptied, the next cycle may begin in which the at least one processor causes the feed device to pump fluid into the empty (or substantially empty) bowl while the bowl rotates at the relatively lower first rotational speed.

In an example embodiment, the at least one processor is operative to determine
5 when the bowl is substantially filled with fluid (but is not yet discharging liquid from a discharge port) by monitoring relative levels of vibrational movement experienced by portions of the centrifuge as the bowl is being filled with liquid. In an example
embodiment, the centrifuge may include a vibration sensor 108 mounted to a stationary
portion 102 of the centrifuge. Such a stationary portion may correspond to a portion of
10 the housing that surrounds a shaft/spindle that is in operative connection with the bowl. However, it is to be understood that the vibration sensor (or additional vibration sensors) may be mounted to other portions of the centrifuge to measure vibrational movement. In this described example embodiment, the vibration sensor may correspond to an
accelerometer or any other type of vibration sensor that is operative to generate vibration
15 data representative of vibrational movement of portions of the centrifuge.

Figure 2 illustrates a cross-sectional view of a centrifuge 200 that may be adapted to correspond to the described system. In this example, the centrifuge 200 corresponds to a UniFuge manufactured by Pneumatic Scale Angelus. Here the centrifuge includes a
bowl 204 that is connected to a spindle 220. The drive device includes a motor 206 that
20 is operative to rotate the spindle 220, via an operatively connected belt 222 and pulley 224. In this example, which represents an example attachment configuration for a vibration sensor, the vibration sensor corresponds to an accelerometer 208 which is mounted to a portion of a housing or bracket 202. The bracket is positioned below the spindle 220, attached to the non-rotating spindle housing 221, and surrounds the pulley
25 224. Figure 2 also shows an example of a centrate discharge port 214 through which liquid is discharged, as well as a feed port 210 through which a feed device (not shown) pumps suspension into the bowl 204.

Figure 3 illustrates a cross-sectional view of a further centrifuge 300 that may be adapted to correspond to the described system. In this example, the centrifuge 300
30 corresponds to a ViaFuge manufactured by Pneumatic Scale Angelus. As with previously described systems, the centrifuge includes a bowl 304 that is connected to a spindle 320. The drive device includes a motor 306 that is operative to rotate the spindle 320, via an

operatively connected belt 322 and pulley 324. As in other embodiments, at least one vibration sensor 308 may be mounted to a non-rotating component such as the bowl case 302 or other stationary portion of the centrifuge. Figure 3 also shows an example of a centrate discharge port 314 through which liquid is discharged, as well as a feed port 310
5 through which a feed device (not shown) pumps fluid into the bowl 304.

Figure 4 illustrates an example graph 400 of vibration data from a system corresponding to that shown in Figure 2. The vibration data was captured beginning at a first time period 402 while the bowl 204 was empty and spinning at the previously described relatively lower first rotation speed (which was 1700 RPM in this example).
10 Subsequently, at a second time period 404 (starting at about 35 seconds in this example) the bowl was filled with a feed fluid (at a rate of 1000 ml/min in this example). As shown in the graph 404, the resulting vibration data reflects a relative increase in vibrational movement of the centrifuge compared to the vibrational movement before the bowl was being filled during the first time period (e.g., before about 35 seconds in this example).

15 This relatively increased level of vibrational movement continues until the bowl is at least 85% filled with fluid, whereafter the level of vibrational movement returns at a third time period 406 (greater than about 125 seconds in this example) to a lower level that, in this case, is relatively similar to the vibration level associated with the first time period 402 (below about 35 seconds in this example).

20 In an example embodiment of the system, the at least one processor may be operative to monitor the vibration data in order to determine when it is indicative of the bowl being substantially filled (e.g., greater than 85% filled). For example, the at least one processor may be operatively programmed to continuously monitor the vibration data (after fluid begins being pumped into the bowl) in order to detect when the vibration data
25 returns to a specified level or passes through a predetermined sequence of vibration values. To determine an initial level, each time a fill cycle is about to begin, (i.e., when an empty or substantially empty bowl is spinning and prior to the at least one processor causing the feed device to begin feeding fluid into the bowl), the at least one processor may be operatively programmed to determine an average, or some other value, derived
30 from the initial vibration level for the bowl. This derived value may then be continuously compared to current vibration measurements to determine when the bowl is substantially filled. Some form of noise reduction may be also applied to the vibration signal.

As shown in the graph 400, the vibration data may temporarily indicate a relative drop in vibration data before the bowl is substantially filled (e.g., see the graph 400 at about 90 seconds). Thus to avoid such temporary drops prematurely causing the processor to improperly detect when the bowl is substantially filled bowl, the at least one processor may be operatively programmed to continually average the most recent vibration data over several seconds to verify that the current vibration level of the bowl has indeed dropped to a continuous average level that is substantially similar to the determined average initial vibration level for when the bowl was empty. Other data reduction schemes may be used to prevent false "bowl is full" determinations. As used herein the substantially similar level corresponds to the current average vibration level being within a predetermined threshold range of the determined average initial vibration level for when the bowl was empty during the current cycle (or a previous cycle).

Also, it is to be understood that the at least one processor may be operatively programmed to monitor other characteristics of vibration data that may be indicative of the bowl being substantially filled. For example, in addition to monitoring average levels of the magnitude of vibrational movement in the bowl, the at least processor may be operative to evaluate vibration data for different axes, harmonics, or any other information that may indicate when the bowl is substantially filled.

In addition, it should be noted that the graph 400 was generated in a system in which the bowl was allowed to be continually filled with the feed fluid, until liquid began overflowing from the discharge port (at about 135 seconds in this example). However, it is to be understood that in example embodiments of the described system, when the processor determines that the bowl is substantially filled responsive to the vibration data, the at least one processor may be operative to stop the feed of fluid into the bowl and cause the rotational speed of the bowl to increase to the previously described relatively higher second rotational speed, before the liquid overflows into the discharge port (at about 135 seconds in this example).

In addition, it should also be noted that the same bowl may be reused for many cycles. Thus at the beginning of a second or subsequent cycle (i.e. after one cycle, but before new fluid is pumped into the bowl), the bowl may be substantially empty, but not completely empty. This may occur because residual solids and or liquid from the

previous cycle may remain along the walls or bottom of the bowl after the bulk of the solids from previous cycles were pumped out of the bowl.

Further, it should be noted that the vibration data may indicate a substantially filled bowl at different fill levels depending on the geometry of the bowl, rotational speed
5 of the bowl, characteristics of the fluid in the bowl, and other physical attributes of the centrifuge and the processing application. Thus as used herein a substantially filled bowl generally corresponds to a bowl that is more than 75% full and less than or equal to 100% full by volume, wherein after the bowl is 100% full, liquid begins to overflow into a discharge port.

10 In example embodiments of the system, the at least one processor may also be operative to monitor the vibration data for the presence of excessive vibrational movement that may damage the system or otherwise negatively impact the operational characteristics of the centrifuge. When such excessive vibrational movement is detected (e.g., via comparison of the vibration data to a predetermined threshold), the at least one
15 processor may be operatively programmed to reduce the rotational speed at which the drive device spins the bowl and/or reduce the feed rate at which the feed device pumps fluid into the bowl. Also, the at least one processor may be operative to output alarm signals and or stop the processing of the centrifuge, when excessive vibrational movement continues to be detected.

20 With reference now to Fig. 5, an example methodology is illustrated and described associated with the operation of the previously described example systems. While the methodology is described as being a series of acts that are performed in a sequence, it is to be understood that the methodologies are not limited by the order of the sequence. For instance, some acts may occur in a different order than what is described herein. In
25 addition, an act may occur concurrently with another act. Furthermore, in some instances, not all acts may be required to implement a methodology described herein.

Moreover, the acts described herein may be caused by computer-executable instructions that can be implemented by one or more processors and/or stored on a computer-readable medium or media. The computer-executable instructions may include
30 a routine, a sub-routine, programs, a thread of execution, and/or the like. Still further, results of acts of the example methodologies may be stored in a computer-readable medium, displayed on a display device, and/or the like.

As illustrated in Figure 5, the methodology 500 begins at 502, and at 504 includes a step of causing a feed device (e.g., pump) to feed a fluid (e.g., a liquid-solid suspension) into a bowl of a centrifuge when the bowl is substantially empty of such fluid.

Continuing at step 506, the methodology may include a step of determining from
5 vibration data that the bowl has become substantially filled with the fluid. Responsive to this determination, the methodology may include a step 508 of causing the feed device to stop feeding the fluid into the bowl and of step 510 of causing a drive device to increase the rotational speed of the bowl. Also after a predetermined amount of time after the rotational speed has been increased, the methodology may include a step 512 of causing
10 the feed device to resume feeding the fluid into the bowl.

This described process may then end at 514. However, it is to be understood that the methodology may involve additional steps to continue processing the fluid through one or more cycles of filling and emptying the bowl. For example, when the bowl has become filled with solids, the methodology may include a step of pumping solids or
15 otherwise discharging solids out of the bowl to place the bowl in a substantially empty condition that is ready for a further cycle.

As used herein, the described at least one processor 112 may be included in a computing device (such as a computer or a dedicated controller) that executes instructions that are stored in a memory as software or firmware. The instructions may be, for
20 instance, instructions for causing devices of the described system to operate or instructions for implementing one or more of the methods described above. The processor may access the memory by way of a system bus or other type of memory controller/bus.

The described computing device may include an input interface that allows
25 external devices and/or users to communicate with the computing device. For instance, the input interface may be used to receive instructions from an external computer device and/or a user. The computing device may also include an output interface that interfaces the computing device with one or more external devices and/or a user. For example, the computing device may display text, images, etc. by way of the output interface.

30 Additionally, while illustrated as a single system, it is to be understood that the computing device may be a distributed system. Thus, for instance, the processor and

several devices may be in communication by way of a network connection and may collectively perform tasks described as being performed by the described systems.

It is noted that several examples have been provided for purposes of explanation. These examples are not to be construed as limiting the hereto-appended claims.

- 5 Additionally, it may be recognized that the examples provided herein may be permuted while still falling under the scope of the claims.

CLAIMS

What is claimed is:

1. A system comprising:

5

a centrifuge including:

a stationary portion;

10

a bowl operative to rotate with respect to the stationary portion;

a drive device operative to selectively control a rotational speed of the bowl;

15

at least one vibration sensor operative to generate vibration data representative of vibrational movement of portions of the centrifuge;

a feed device operative to selectively cause a fluid to be fed into the bowl, wherein the fluid includes a liquid and solids;

20

at least one processor operatively configured to cause the drive device to increase the rotational speed of the bowl responsive to the at least one processor determining from the vibration data that the bowl has become substantially filled with the fluid.

25

2. The system according to claim 1, wherein the at least one processor is operatively configured to cause the feed device to stop feeding the fluid into the bowl responsive to the at least one processor determining from the vibration data that the bowl has becoming substantially filled with the fluid.

30

3. The system according to claim 2, wherein the at least one processor is operatively configured to cause the feed device to begin filling the bowl with the fluid, wherein when the bowl is empty or substantially empty, the at least one processor is operatively configured to determine from the vibration data, an initial vibration level representative of vibrational movement in the centrifuge prior to the feed control operating to fill the bowl with the fluid, wherein during filling of the bowl with the fluid, the at least one processor is operatively configured to determine when the vibration data is indicative of the bowl becoming substantially filled with the fluid, responsive to the vibration data corresponding to vibrational movement in the centrifuge that has dropped to a vibration level that is substantially similar to the determined initial vibration level.
4. The system according to claim 3, wherein the centrifuge includes a discharge port, wherein the at least one processor is operatively configured to determine from the vibration data that the bowl has becoming substantially filled with the fluid prior to liquid in the bowl beginning to overflow from the bowl through the discharge port.
5. The system according to claim 4, wherein the at least one vibration sensor is mounted to the stationary portion of the centrifuge.
6. The system according to claim 5, wherein the at least one vibration sensor is an accelerometer.
7. The system according to claim 5, wherein the drive device includes a motor, wherein the feed device includes a pump, wherein the at least one processor is operatively configured to control the operation of the motor and the pump based in part on the vibration data.
8. A method comprising:
- a) through operation of the at least one processor, causing a feed device to feed a fluid into a bowl of a centrifuge when the bowl is empty or substantially empty, wherein the fluid includes a liquid and solids, wherein the centrifuge

includes a stationary portion, wherein the bowl is operative to rotate with respect to the stationary portion, wherein the centrifuge includes a drive device operative to selectively control a rotational speed of the bowl, wherein the centrifuge includes at least one vibration sensor operative to generate vibration data representative of vibrational movement of portions of the centrifuge;

- 5
- b) through operation of the at least one processor, determining from the vibration data that the bowl has becoming substantially filled with the fluid;
- 10 c) responsive to (b), through operation of the at least one processor, causing the drive device to increase the rotational speed of the bowl.

9. The method according to claim 8, further comprising:

- 15 d) responsive to (b), through operation of the at least one processor, causing the feed device to stop feeding the fluid into the bowl.

10. The method according to claim 9, further comprising:

- 20 e) prior to (a) through operation of the at least one processor, when the bowl is empty or substantially empty, determining from the vibration data an initial vibration level representative of vibrational movement in the centrifuge;

wherein in (b) the at least one processor determines when the vibration data is indicative of the bowl becoming substantially filled with the fluid responsive to the vibration data corresponding to vibrational movement in the centrifuge that has dropped to a vibration level that is substantially similar to the initial vibration level determined in (e).

11. The method according to claim 10, wherein the centrifuge includes a discharge port, wherein in (b) the at least one processor determines from the vibration data that the bowl has becoming substantially filled with the fluid prior to liquid in the bowl beginning to overflow from the bowl through the discharge port.

12. The method according to claim 11, wherein in (b) and (e) the at least one vibration sensor is mounted to the stationary portion of the centrifuge.

5 13. The method according to claim 12, wherein in (b) and (e) the at least one vibration sensor is an accelerometer.

14. The method according to claim 12, wherein the drive device includes a motor, wherein the feed device includes a pump, wherein (c) includes the at least one processor, causing the motor to increase the rotational speed of the bowl, wherein (d) includes the at
10 least one processor causing the pump to stop feeding the fluid into the bowl.

15. A computer-readable medium comprising instructions that, when executed by at least one processor, perform the following acts:

15

a) through operation of the at least one processor, causing a feed device to feed a fluid into a bowl of a centrifuge when the bowl is empty or substantially empty, wherein the fluid includes a liquid and solids, wherein the centrifuge includes a stationary portion, wherein the bowl is operative to rotate with respect
20 to the stationary portion, wherein the centrifuge includes a drive device operative to selectively control a rotational speed of the bowl, wherein the centrifuge includes at least one vibration sensor operative to generate vibration data representative of vibrational movement of portions of the centrifuge;

25

b) through operation of the at least one processor, determining from the vibration data that the bowl has becoming substantially filled with the fluid;

c) responsive to (b), through operation of the at least one processor, causing the drive device to increase the rotational speed of the bowl.

30

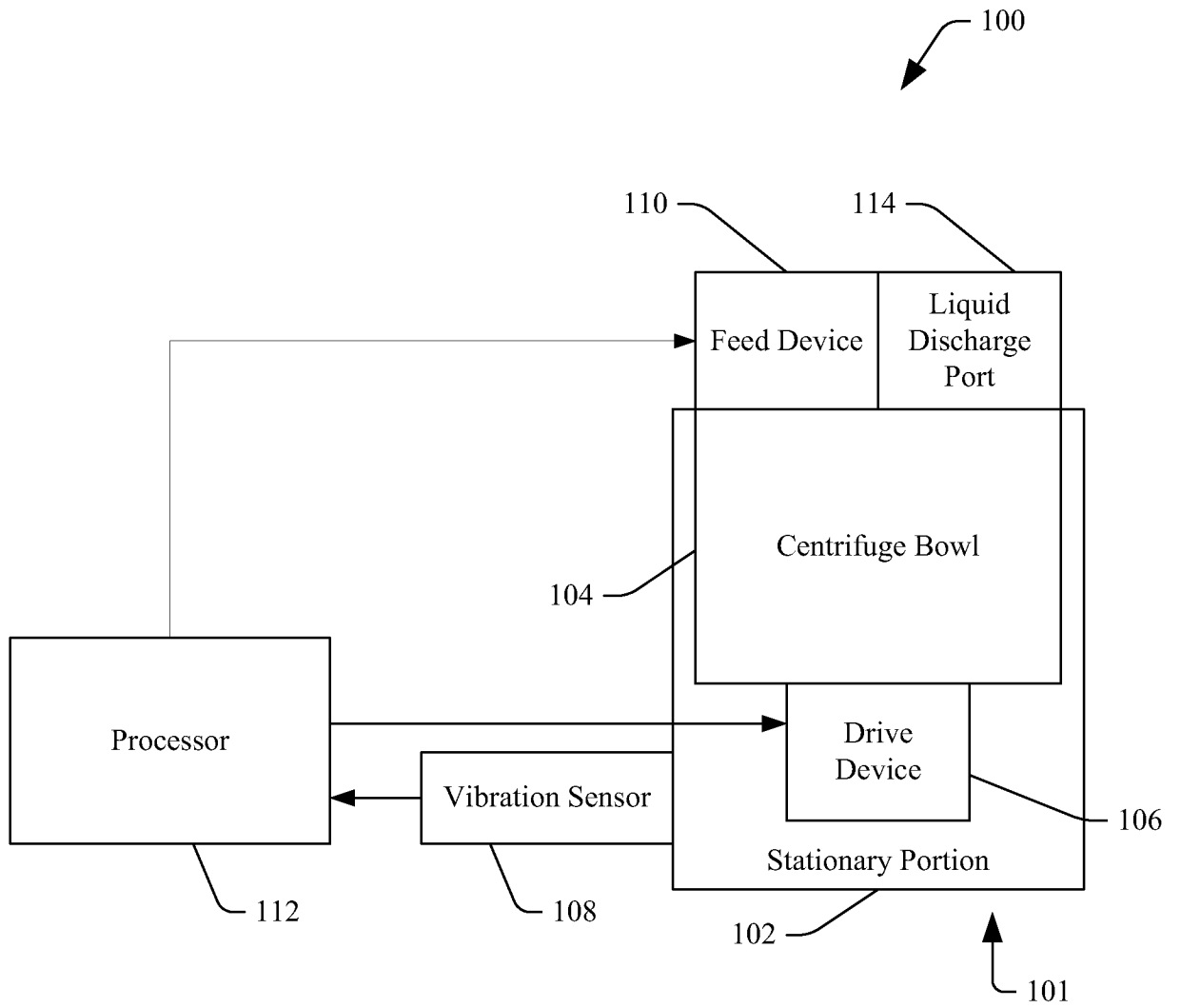


FIG. 1

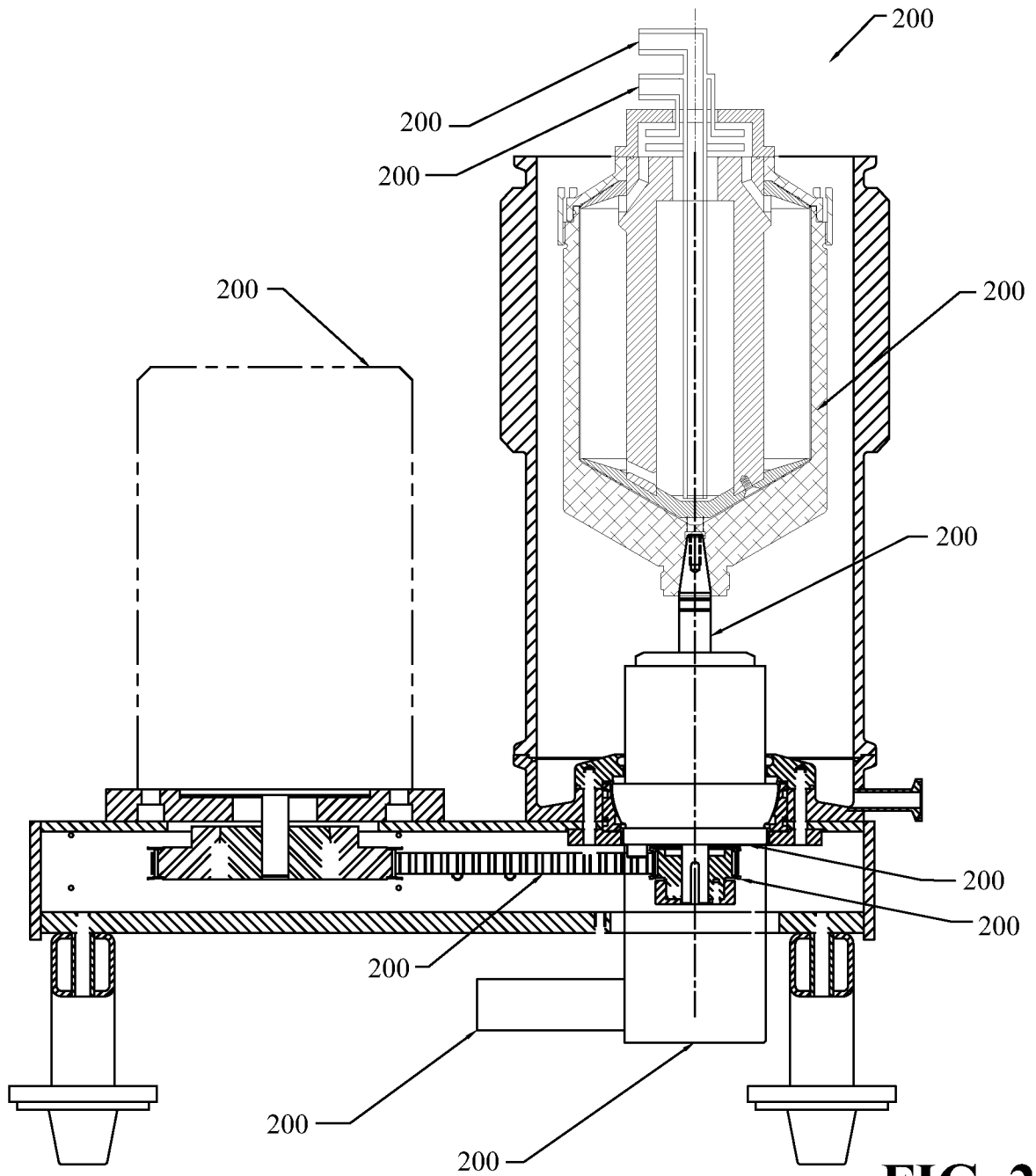


FIG. 2

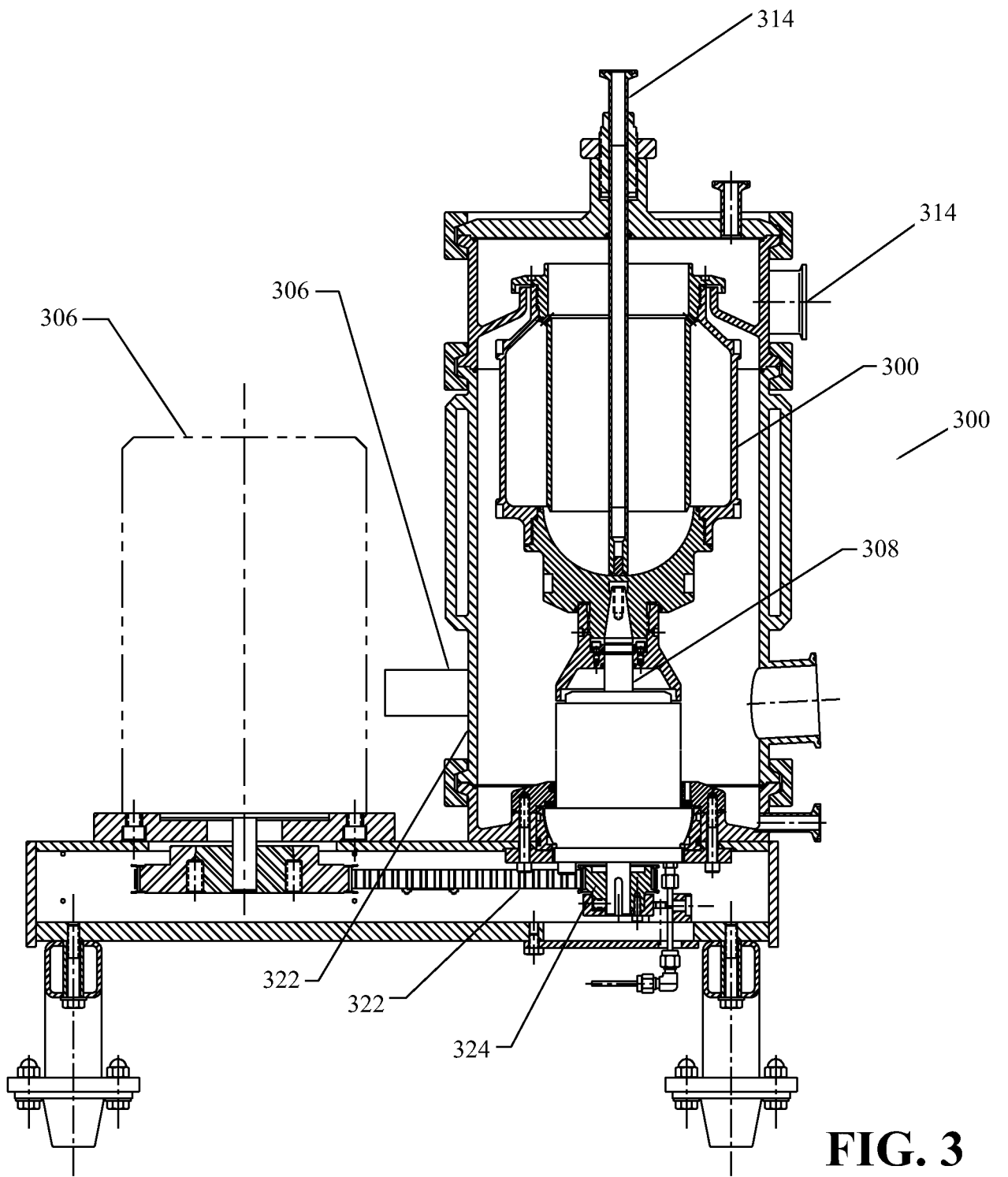


FIG. 3

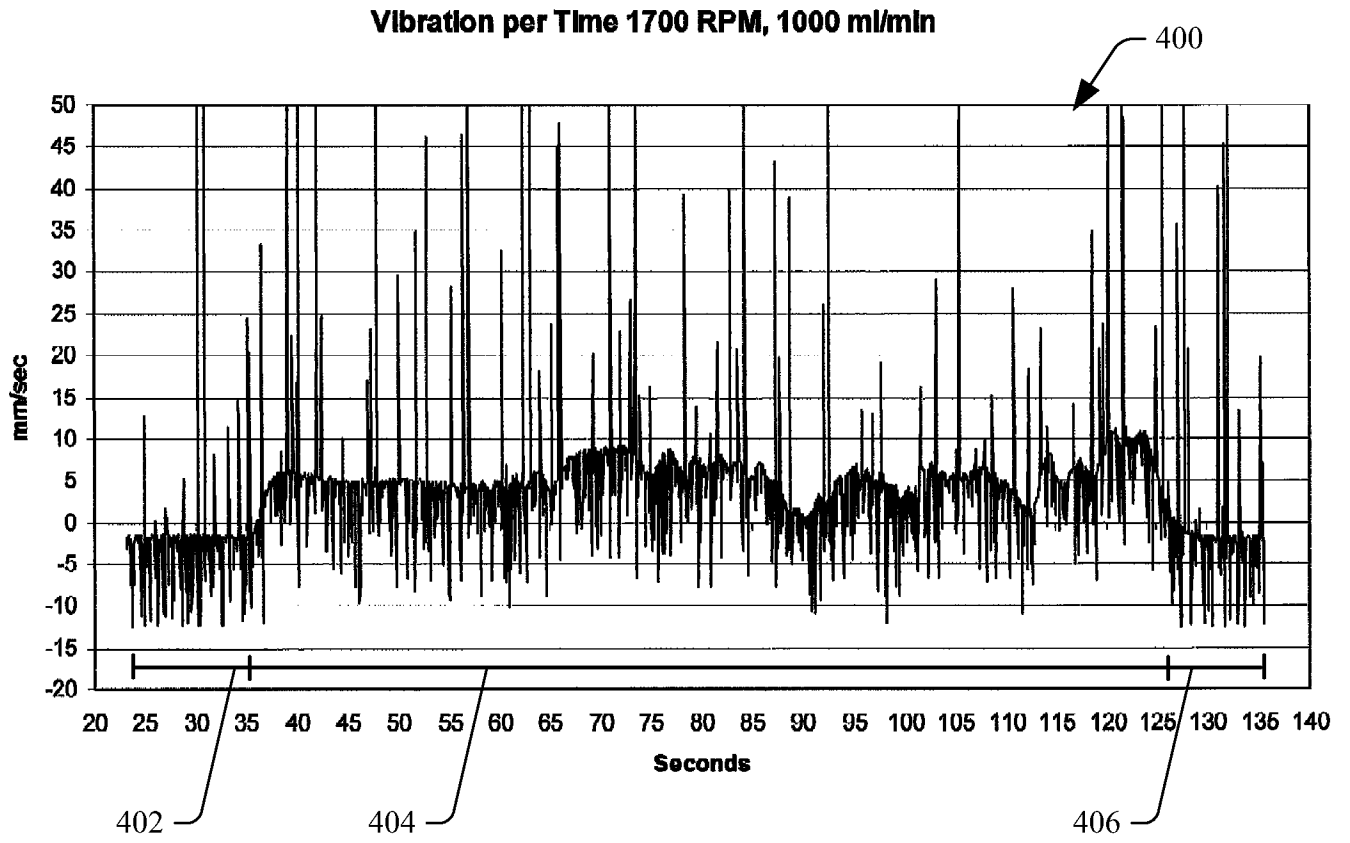
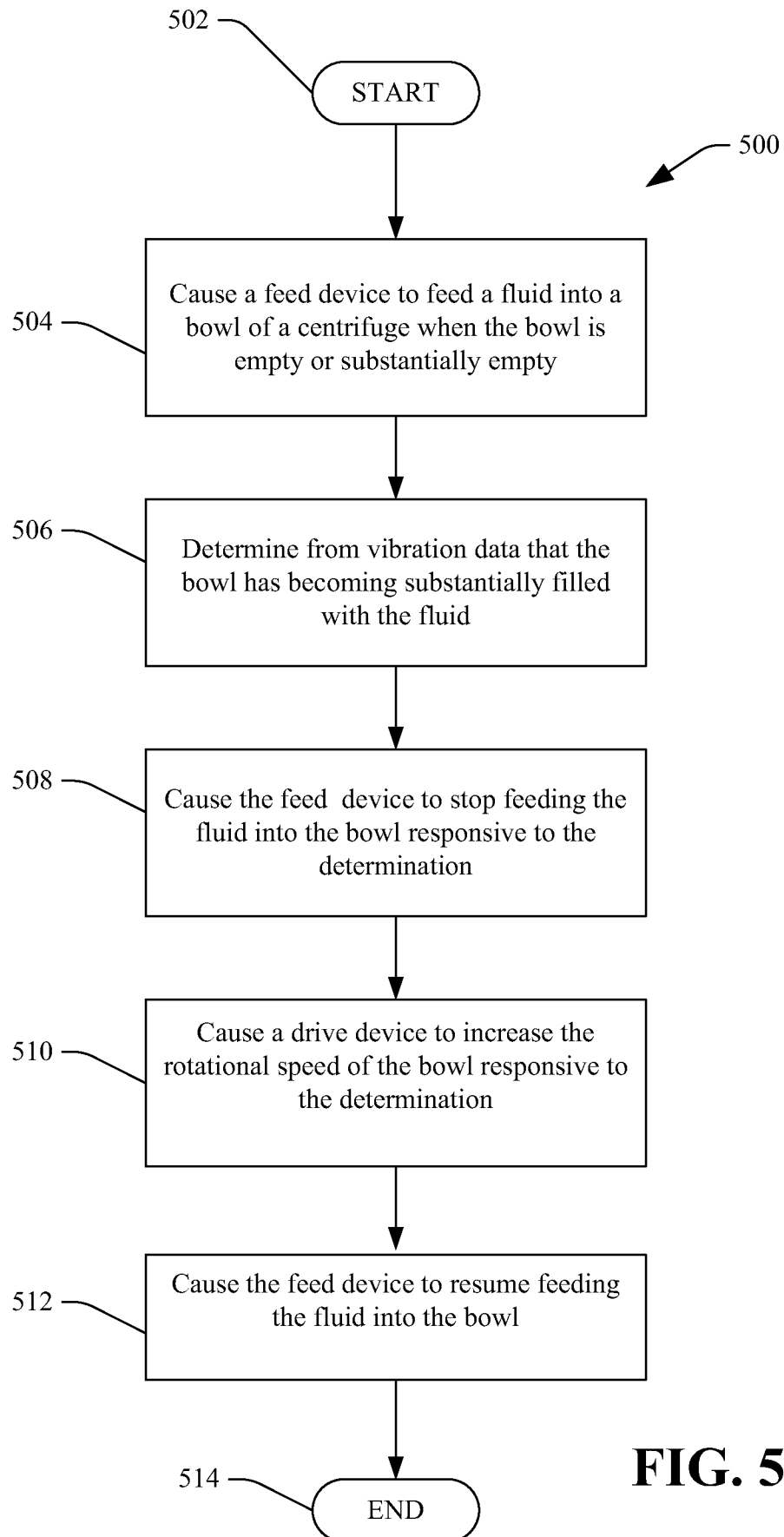


FIG. 4

5/5

**FIG. 5**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/30130

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - B04B 9/10,13/00 (2011.01)
 USPC - 494/7
 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)
 USPC: 494/7

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 USPC: 494/1,7,8,9,10,82,84; 210/85,144
 (keyword limited; terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 PubWEST (PGPB, USPT, EPAB, JPAB); Google
 Search terms: centrifuge, separator, vibrate, jitter, wobble, balance, unbalance, sense, detect, monitor, et al.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2008/0234121 A1 (Kim et al.) 25 September 2008 (25.09.2008), para [0075]-[0086], Fig 2, 3	1-15
Y	US 6,296,774 B1 (Henkel et al.) 2 October 2001 (02.10.2001), abstract, col 9, ln 54-61	1-15
A	US 2003/0101519 A1 (Gayme et al.) 5 June 2003 (05.06.2003), entire document	1-15
A	US 6,350,224 B1 (Cordaro et al.) 26 February 2002 (26.02.2002), entire document	1-15
A	US 2010/0009833 A1 (Ryu et al.) 14 January 2010 (14.01.2010), entire document	1-15
A	US 5,948,271 A (Wardwell et al.) 7 September 1999 (07.09.1999), entire document	1-15

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance	“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
“E” earlier application or patent but published on or after the international filing date	“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
“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	“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
“O” document referring to an oral disclosure, use, exhibition or other means	“&” document member of the same patent family
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 12 May 2011 (12.05.2011)	Date of mailing of the international search report 01 JUN 2011
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774