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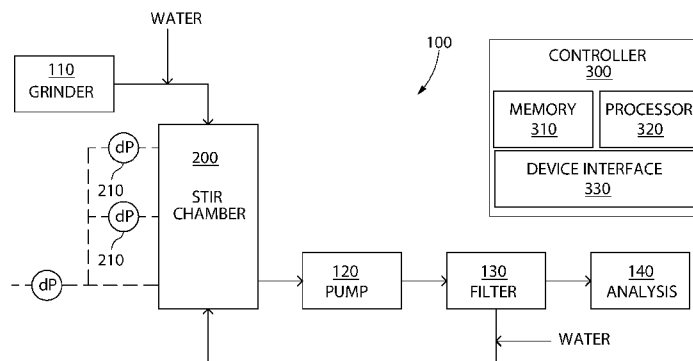


FIG. 1

(57) Abstract: An agricultural slurry analysis system includes a stirring device comprising an upper housing section and mechanically isolated lower housing section defining a stir chamber which receives agricultural sample slurry, a strain gauge coupled to the chamber which measures weight of the stir chamber with and without slurry, and a level sensor which measures a level of the slurry in the chamber. The strain gauge and level sensor are operably coupled to a programmable controller configured to: receive actual weight measurements of the stir chamber via the strain gauge; determine a weight of the slurry in the stir chamber based on the actual weight measurements; receive an actual slurry level measurement from the level sensor; and determine a density of the slurry based on the actual weight and slurry level measurements. The controller also determines water/solids ratio of the slurry and adjusts the same until a target ratio is met.

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## **SYSTEM FOR AGRICULTURAL SAMPLE SLURRY ANALYSIS AND RELATED METHODS**

### **CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority to U.S. Application No. 63/508341, filed 15 June 2023, which is incorporated herein by reference in its entirety.

### **BACKGROUND**

[0002] The present disclosure generally relates to agricultural sampling and analysis, and more particularly to a system and associated apparatuses for analyzing a slurry from an agricultural material sample such as soil.

[0003] Periodic soil testing is an important aspect of the agricultural arts. Test results provide valuable information on the chemical makeup of the soil such as plant-available nutrients and other important properties (e.g., levels of nitrogen, magnesium, phosphorous, potassium, pH, etc.) so that various amendments may be added to the soil to maximize the quality and quantity of crop production.

[0004] In some sampling and chemical analysis processes, the raw or bulk agricultural material samples such as soil (or other agricultural materials) extracted from the field may be prepared for analysis. During analysis, the sample may be measured for various properties. Measurements may be performed to determine the chemical makeup or may be performed to ensure adequate sample size, density, or other parameters that may affect the quality of other measurements. In still other processes, measurements may be made and corrective actions taken to ensure the quality of the measurements.

[0005] Improvements in agricultural sample preparation and analysis are desired.

### **BRIEF SUMMARY**

[0006] The present disclosure provides a stir chamber apparatus and system and related method of use for analyzing a fluid sample. In some embodiments, the sample is an agricultural sample collected from the agricultural field or farm. The sample may be a soil sample in some non-limiting embodiments, or other agricultural-related materials described further herein amenable to chemical and other types of analysis.

[0007] In one aspect, a stir chamber has a housing, a first sensor, a second sensor, and a third sensor. The housing defines an internal cavity configured to receive an agricultural sample. The internal cavity extends along a longitudinal axis from a bottom end to a top end. The first sensor is fluidly coupled to the internal cavity of the housing at a first location with respect to the longitudinal axis. The second sensor is fluidly coupled to the internal cavity of the housing at a second location with respect to the longitudinal axis. The third sensor is fluidly coupled to the internal cavity of the housing at a third location with respect to the longitudinal axis. The second location is located between the first and third locations. The first, second, and third sensors are configured to monitor one of a fluid level or a density of the sample.

[0008] In another aspect, a system for analyzing an agricultural sample has a stir chamber and a controller. The stir chamber has a housing, a first sensor, and a second sensor. The housing defines an internal cavity configured to receive an agricultural sample. The internal cavity extends along a longitudinal axis from a bottom end to a top end. The first sensor is fluidly coupled to the internal cavity of the housing at a first location with respect to the longitudinal axis. The second sensor is fluidly coupled to the internal cavity of the housing at a second location with respect to the longitudinal axis. The controller is configured to receive a plurality of signals from the first and second sensors. At least one of the plurality of signals is used to compute a density of a first region of the internal cavity located between the first and second sensors.

[0009] In yet another aspect, a method for analyzing a sample has a first step of providing a chamber having an internal cavity, the internal cavity extending along a longitudinal axis from a bottom end to a top end. Second, the first sensor is fluidly coupled to the internal cavity at a first location with respect to the longitudinal axis and a second sensor is fluidly coupled to the internal cavity at a second location with respect to the longitudinal axis. Third, a sample is added to the internal cavity. Fourth, a plurality of signals from the first and second sensors are read. Fifth, a density or a fluid level is computed using the plurality of signals from the first and second sensors.

[0010] Although the stir chamber apparatus, system, and related methods or processes for preparing an agricultural sample slurry may be described herein with reference to soil samples for convenience of description, this represents only a single category of use for the disclosed embodiments of the invention. It will therefore be understood that the same apparatus and related methods or processes may be used for processing any type of sample, not limited to agricultural samples. These samples may include any liquid, including liquid solutions and suspensions. The

disclosure herein should therefore be broadly construed as an apparatus and related methods or processes for analyzing the sample regardless of the type of material or method of collection.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0011] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein like elements are labeled similarly and in which:

[0012] FIG. 1 is a schematic of an exemplary system for analyzing an agricultural sample;

[0013] FIG. 2 is a perspective view of a stir chamber as may be used in the exemplary system for analyzing an agricultural sample as shown in FIG. 1;

[0014] FIG. 3 is a cross sectional view of the stir chamber of FIG. 2, taken along line 3-3;

[0015] FIG. 4 is a cross sectional view of the stir chamber of FIG. 3, taken along line 4-4;

[0016] FIG. 5 is a cross sectional view of the stir chamber of FIG. 2, taken along line 5-5;

[0017] FIG. 6 is a cross sectional view of the stir chamber of FIG. 2, taken along line 6-6;

[0018] FIG. 7 is a schematic view of an alternate embodiment of a stir chamber as may be used in the system of FIG. 1;

[0019] FIG. 8 is a flow chart illustrating a method for analyzing a sample;

[0020] FIG. 9 is a schematic system block diagram of an alternative system for processing analyzing an agricultural sample;

[0021] FIG. 10 is a first top perspective view of a stirring device of the system of FIG. 9 comprising a stir chamber for processing and analyzing an agricultural sample slurry;

[0022] FIG. 11 is a second top perspective view thereof;

[0023] FIG. 12 is a first bottom perspective view thereof;

[0024] FIG. 13 is a second bottom perspective view thereof;

[0025] FIG. 14 is a first side view thereof;

[0026] FIG. 15 is a second side view thereof;

[0027] FIG. 16 is a third side view thereof;

[0028] FIG. 17 is a fourth side view thereof;

[0029] FIG. 18 is a top view thereof;

[0030] FIG. 19 is a bottom view thereof;

[0031] FIG. 20 is a first longitudinal cross sectional view thereof;

[0032] FIG. 21 is an enlarged detail from FIG. 20;

[0033] FIG. 22 is a second longitudinal cross sectional view of the stirring device of FIG. 10;

[0034] FIG. 23 is an enlarged detail from FIG. 22; and

[0035] FIG. 24 is transverse cross sectional view of the stir chamber of the stirring device.

[0036] All drawings are schematic and not necessarily to scale. Components numbered and appearing in one figure but appearing un-numbered in other figures are the same components unless expressly noted otherwise. Any reference herein to a figure by a whole figure number which may appear in multiple figures bearing the same whole number prefix but with different alphabetical suffixes shall be construed as a general reference to all of those figures unless expressly noted otherwise.

### **DETAILED DESCRIPTION**

[0037] The features and benefits of the present disclosure are illustrated and described herein by reference to exemplary (“example”) embodiments. This description of exemplary embodiments is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description. Accordingly, the disclosure expressly should not be limited to such exemplary embodiments illustrating some possible non-limiting combination of features that may exist alone or in other combinations of features.

[0038] In the description of embodiments disclosed herein, any reference to direction or orientation is merely intended for convenience of description and is not intended in any way to limit the scope of the present disclosure. Relative terms such as “lower,” “upper,” “horizontal,” “vertical,” “above,” “below,” “up,” “down,” “top” and “bottom” as well as derivative thereof (e.g., “horizontally,” “downwardly,” “upwardly,” etc.) should be construed to refer to the orientation as then described or as shown in the drawing under discussion. These relative terms are for convenience of description only and do not require that the apparatus be constructed or operated in a particular orientation. Terms such as “attached,” “affixed,” “connected,” “coupled,” “interconnected,” and similar refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise.

[0039] As used throughout, any ranges disclosed herein are used as shorthand for describing each and every value that is within the range. Any value within the range can be selected as the terminus of the range. In addition, all references cited herein to prior patents or patent applications are hereby incorporated by reference in their entireties. In the event of a conflict in a definition in the present disclosure and that of a cited reference, the present disclosure controls.

**[0040]** FIG. 1 illustrates a schematic view of a system for analyzing an agricultural sample 100. The system 100 comprises a grinder 110, a stir chamber 200, a pump 120, a filter 130, and an analysis unit 140. The grinder 110 receives an agricultural sample, such as soil, and grinds the sample to ensure that the maximum particle size of the agricultural sample is below that required for later analysis by the analysis unit 140. Examples of grinders which may be used can be found in commonly-owned U.S. Application Nos. 17/326050 filed 20-May-2021; 63/191186 filed 20-May-2021; 63/191189 filed 20-May-2021; 63/191195 filed 20-May-2021; 63/191199 filed 20-May-2021; 63/191204 filed 20-May-2021; and 63/507,517, filed 12 June 2023. For instance, clumps of soil and plant matter may be ground to reduce them in size so that they are suitable for passing through the system. In addition, water may be added from a fluid source to facilitate effective grinding and provide a liquid slurry that eases passage of the sample through the system and is ultimately used for final analysis by analysis unit 140.

**[0041]** The sample (i.e. slurry) then passes from the grinder 110 to the stir chamber 200. The purpose of the stir chamber 200 is to ensure that the agriculture sample is homogeneous. This may be performed by a variety of methods, including mixing, stirring, shaking, vibrating, or any other means suitable to ensure thorough mixing of the sample. In addition, measurements may be performed on the sample to verify that adequate mixing has occurred. For instance the level of the sample within the stir chamber 200, the density, or the mass may be measured in an effort to determine adequate sample size and homogeneity. Once again, water may be added from a fluid source to achieve a target density, improve homogeneity, or other purposes. The fluid source may recycle water used elsewhere in the process or may add new water. In addition, the sample may be returned to the stir chamber from downstream components to perform additional processing as will be discussed in greater detail below.

**[0042]** From the stir chamber 200, the sample passes to a pump 120. The pump 120 pressurizes the sample to ensure that it is effectively filtered by a filter 130. In other implementations, the pump 120 may be located downstream of the filter 130, such that the filter 130 is on the suction side of the pump 120. The pump 120 and filter 130 may be used to remove undesirably large components of the sample such as gravel that have passed through the grinder. The pump 120 and filter 130 may also be used to recirculate a portion of the sample along with additional water from a water source to enable additional treatment and adjustment of the sample slurry in the stir chamber 200. This may be done because only a portion of the sample is required for further testing.

It is also possible to iteratively adjust the density, water/solids ratio, and homogeneity of the sample to facilitate further analysis.

**[0043]** Once the sample has passed through the filter 130, the analysis unit 140 performs further analysis on some or all of the sample. This analysis may include measurement of physical properties such as density or mass. The analysis may also include a range of chemical analyses. Subsequently, the sample may be discarded. Additional water from one or more of the fluid sources may be used to flush the system and ensure accurate measurement of a future sample.

**[0044]** A controller 300 controls all functions of the stir chamber 300. The controller 300 comprises a memory 310, a processor 320, and a device interface 330. The controller 300 may be a central controller which controls functions for all components of the system. In other implementations 300, the controller 300 may be integrated into a single component such as the stir chamber 200. In this implementation, additional controllers 300 may be integrated into the other components and may communicate via a bus or other communications system. Alternately, the controller 300 may be integrated into a single component and may also connect to other components in the system. As can be seen, the arrangement of the controller 300 may be distributed or may be centralized as desired.

**[0045]** The stir chamber 200 has a plurality of sensors 210. In the system 100, the sensors 210 are differential pressure sensors. The sensor 210 are coupled to the stir chamber 200 as illustrated, with each sensor 210 having a first side of the differential sensor coupled to the stir chamber 200. A second side of the sensor 210 may also be coupled to the stir chamber 200 or may be coupled to atmosphere as illustrated in Fig. 1. Any number of sensors 210 may be utilized as desired.

**[0046]** In some embodiments, all of the second sides of the sensors 210 are coupled to atmosphere and in some other embodiments, all of the second sides of the sensors 210 are coupled to the stir chamber. As can be seen, all, some, or none of the second sides of the sensors 210 may be coupled to atmosphere and all, some, or none of the second sides may be coupled to the stir chamber 200. In yet further embodiments, the sensors 210 may be absolute, atmospheric, or gauge type sensors having only a single sensing input rather than the two sides or inputs of a differential sensor. In yet other configurations, the sensors 210 may not be pressure sensors, and may instead be optical, capacitive, ultrasonic, microwave, vibrating, ultrasonic, conductivity, laser, nuclear, or other types of sensors suitable for measuring density, fluid level, pressure, or other properties of a sample.

Multiple different types of sensors 210 may be utilized, and not all sensors 210 need be the same type.

[0047] Turning to Figs. 2-6, an exemplary embodiment of a stir chamber 200 is illustrated. The stir chamber has a housing 220 formed of a gear head 221, an upper housing 222, a middle housing 223, and a lower housing 224. The gear head 221 receives a motor 225 and couples to the upper housing 222. The upper housing 222, middle housing 223, and lower housing 224 collectively form an internal cavity 230. The internal cavity 230 extends along a longitudinal axis A-A, the internal cavity 230 being elongate along the longitudinal axis A-A. The internal cavity 230 extends along the longitudinal axis A-A from a top end 231 to a bottom end 232.

[0048] A plurality of ports 240 are formed into the housing 220 and are fluidly coupled to the internal cavity 230. The ports 240 may serve a variety of functions, including receiving a sample, outputting a sample, permitting sensors to measure the sample, allowing for injection of fluid such as water from a fluid source, or any other desired function. Optionally, some of the ports 240 may be plugged and may be utilized for optional functions which are not implemented in every system.

[0049] The plurality of ports 240 comprise a first sensing port 241, second sensing port 242, and third sensing port 243. The first, second, and third sensing ports 241, 242, 243 are arranged along the longitudinal axis A-A and fluidly coupled to the internal cavity 230. Each of the first, second, and third sensing ports 241, 242, 243 are configured to receive a sensor 210. More than three or less than three sensing ports may be utilized. One or two ports may provide adequate opportunities for sensing, while greater than three ports may provide additional granularity to the measured data.

[0050] The housing 220 is generally arranged such that the longitudinal axis A-A is vertical with respect to gravity. This ensures that the sample settles at the bottom end 232 of the internal cavity 230. Thus, a level of the sample within the internal cavity 230 can be measured using the sensing ports 241, 242, 243, with the first sensing port 241 being submerged in the sample last as the sample is delivered to the internal cavity 230.

[0051] The sensors 210 are installed into the first, second, and third sensing ports 241, 242, 243 as noted above. The sensors 210 may incorporate a fluid passage therethrough that allows clearing the first, second, and third sensing ports 241, 242, 243 in the event of clogs or to facilitate a complete rinse of the internal cavity 230. The sensors 210 are thus located at first, second, and third locations with respect to the longitudinal axis A-A. The first, second, and third locations each have a different position along the longitudinal axis A-A. A first region R1 is defined by the

first and second locations of the first and second sensing ports 241, 242. A second region R2 is defined by the second and third locations of the second and third sensing ports 242, 243. A third region R3 overlaps the first and second regions R1, R2 and is defined by the first and third locations of the first and third sensing ports 241, 243.

**[0052]** The three different locations along the longitudinal axis allow measurements to be taken at different heights with respect to the bottom end 232 of the internal cavity 230. The controller 300 is operably coupled to the sensors 210. A plurality of signals from the sensors 210 may be received by the controller 300, allowing data collection from the sensors 210 as will be discussed in greater detail below.

**[0053]** The stir chamber 200 further incorporates an agitator 250. The agitator 250 collectively comprises the motor 225, a gear train 251, and two agitator shafts 252. Each agitator shaft 252 comprises a blade 253 that agitates the sample when the agitator shafts 252 are rotated. The gear train 251 connects the motor 225 to the agitator shafts 252. Optionally, more than one motor 225 may be utilized and the gear train 251 omitted. Optionally, one agitator shaft 252 or more than two agitator shafts 252 may be utilized. In yet other configurations, the gear train 251 may be formed as a belt or chain drive instead of a gear drive, but may still be referred to as a gear train 251. The gear train 251 may serve to reduce or increase the speed of the agitator shafts 252 with respect to the motor 225, or the gear train 251 may provide no reduction or multiplication of the speed of the motor 225.

**[0054]** In one implementation, the stir chamber 200 may utilize the sensors 210 to compute the density of the sample within the internal cavity 230. More specifically, the density of the sample may be measured in different regions within the internal cavity 230. By measuring pressure at two or more locations within the internal cavity 230, these locations being separated by a vertical distance as illustrated by the longitudinal axis A-A, it is possible to compute the density of the sample between these two locations. As long as the sample is a liquid and the locations are submerged in the sample, it is possible to measure the pressure differential at these two locations and calculate the sample's density in the region between these two locations. The fluid may be a suspension and does not need to be perfectly homogeneous.

**[0055]** In one method of calculating the density between two locations, the internal cavity 230 is first emptied such that it is only filled with air. The signals from the sensors 210 are then zeroed such that the readings are corrected for any deviation. Air has negligible pressure differential over

the distances between the sensors 210, so it can be assumed that the pressure differential should be zero. Next, the internal cavity is filled with a reference fluid such as water, with the fluid filling the internal cavity 230 such that it covers the first, second, and third sensing ports 241, 242, 243. The reference fluid must have a known reference density. For example, the reference density of water may be arbitrarily assigned to be 1, or may be in any conventional unit system. Then, a pressure differential between any two locations is measured. For example, the pressure differential may be calculated by the controller 300 based on signals from sensors 210 in the first and second sensing ports 241, 242. Alternately, the first and third sensing ports 241, 243 or the second and third sensing ports 242, 243 may be utilized. The pressure differential between the two locations is then used as a reference differential pressure.

**[0056]** The signals from the sensors 210 are received by the controller 300. The signals from the sensors 210 may be in the form of an analog voltage or current, or may be a digital signal. The signals from the sensors 210 correspond to a parameter measured by the respective sensor 210. The signals may vary with respect to time, and may represent a parameter such as pressure or some other parameter which is continuously changing based on the measured condition at the respective sensing port.

**[0057]** Next, the internal cavity 230 is filled with a fluid of unknown density such as the agricultural sample. Once again, the two locations must be covered by the fluid of the sample. The pressure differential between the two locations is once again measured to determine a specimen differential pressure. The density may be calculated by the following formula: specimen density = reference density \* specimen differential pressure / reference differential pressure. For example, if the reference density is arbitrarily assigned a value of 1, the specimen density can be determined with reference to the reference density. Specimens being twice as dense as the reference fluid would have a specimen density of 2, while specimens having half the density of the reference fluid would have a specimen density of 0.5. Alternately, the density may be defined in terms of any accepted unit system. For instance, density may be defined in terms of grams per cubic centimeter, kilograms per cubic meter, pounds per cubic foot, or any other recognized unit system.

**[0058]** In the event that a reference fluid of known density is not available, the internal volume and location of the sensing ports 241, 242, 243 can be utilized to calculate an expected pressure differential between two ports of a given reference fluid. This can, in turn, be used to compute a

theoretical reference differential pressure that may be utilized to calculate the specimen density using the same equation as is used when an actual reference fluid is used. However, this suffers from some potential loss of accuracy due to variations in internal volume of the internal cavity 230, variations in the location of the sensors 210, and other variables.

**[0059]** Furthermore, a method of determining the mass of the sample can be performed. If the geometry and volume of the internal cavity 230 are known, it is possible to determine the mass of liquid within the region between the two measured points. For instance, in a cylindrical volume, the mass within the internal cavity 230 in the region between the two measured points can be determined by multiplying the specimen density by the volume within the region between the two measured points.

**[0060]** In yet another method, the sensors 210 can be utilized to determine a level of the sample within the internal cavity 230. By comparing the pressure measured by each sensor 210 against atmospheric pressure, the presence or absence of the sample can be determined for each location. In addition, it is possible to calculate a level between the sensors 210 by combining density measurements with pressure measurements. For instance, if the sensor 210 at the first sensing port 241 measures a pressure equal to atmospheric pressure, then the sample must have a level below the location of the first sensing port 241 with respect to the longitudinal axis A-A. If the sensor 210 at the first sensing port 241 measures a pressure greater than atmospheric pressure, then the sample must have a level above the location of the first sensing port 241. In combination with the pressure and density information, a level between ports 240 can be extrapolated. If additional sensing accuracy is desired, additional sensing ports may be added or additional sensors 210 of different types may be utilized.

**[0061]** In yet a further method, information regarding the density within regions of the internal cavity 230 may be used to measure the homogeneity of the sample. Where the sample is an inhomogeneous liquid (i.e. a thin suspension or other liquid of non-uniform density), measuring at three or more points will provide information on the distribution of the density of the sample in three or more regions.

**[0062]** For example, in the present system, the density of the sample can be measured in the first region R1 between the sensor 210 at the first sensing port 241 and the sensor 210 at the second sensing port 242. The density may also be measured in the second region R2 between the sensor 210 at the second sensing port 242 and the sensor 210 at the third sensing port 243. Finally, the

density may be measured in the third region R3 between the sensor 210 at the first sensing port 241 and the sensor 210 at the third sensing port 243. Thus, the density can be measured for the first and second regions R1, R2 and the third region R3 that overlaps both the first and second regions R1, R2. Adding additional sensors 210 at additional sensing ports will allow measurements in additional regions, further increasing the information regarding the homogeneity of the sample.

**[0063]** As can be seen, each of the first, second, and third regions R1, R2, R3 may have different densities. The difference between the densities of the first, second, and third regions R1, R2, R3, allows a quantitative analysis of the homogeneity of the sample within the internal cavity 230. In some implementations, the agitator 250 may be activated in response to detecting a difference in density between two regions that exceeds a predetermined threshold.

**[0064]** In yet other implementations, where the sample has a greater density in the first region R1 than either the second or third regions R2, R3, the speed of the agitator shafts 252, or by extension, the speed of the motor 225, may be reduced to allow particles or other components of the sample to settle toward the bottom end 232 of the internal cavity 230. Where the sample has a lesser density in the first region R1 than either the second or third regions R2, R3, the speed of the agitator shafts 252, or by extension, the speed of the motor 225, may be increased to increase agitation and move particles from the second region R2 to the first region R1.

**[0065]** In each case, the speed of the agitator shafts 252 may be controlled using proportional control or may be activated according to a series of predetermined thresholds, with each threshold corresponding to a difference in density. In other implementations, the speed may be controlled in any known means designed to improve homogeneity of the sample. Any number of regions may be created by any number of sensors 210 as desired.

**[0066]** In other implementations, the sensors 210 need not be located in sensor ports as shown in the embodiment of Figs. 2-6. In other implementations such as that shown schematically in Fig. 7, the sensors 210 may measure pressure at different locations using tubes or probes. Each tube of the sensors 210 terminates at a different location with respect to the longitudinal axis A-A to permit measurement at different heights just as with the embodiment of Figs. 2-6. Otherwise stated, the tube of each sensor 210 terminates at a first, second, or third sensing port 241, 242, 243. A particle distribution within the sample is illustrated as having a different distribution with respect to position along the longitudinal axis A-A.

[0067] The use of an agitator 250 is optional. In some implementations, the agitator 250 may be omitted and density or fluid level measurements may be made without use of the agitator 250. In yet other implementations, the sample need not have suspended solids, but instead may be any fluid, either homogeneous or inhomogeneous.

[0068] In summary, a method for analyzing a sample 400 starts with step 410, providing a chamber 200 having an internal cavity 230. The internal cavity 230 extends along a longitudinal axis from a bottom end 232 to a top end 231. In step 420, a first sensor 210 is fluidly coupled to the internal cavity 230 at a first location with respect to the longitudinal axis A-A. A second sensor 210 is fluidly coupled to the internal cavity 230 at a second location with respect to the longitudinal axis A-A. Optionally, a third sensor 210 is fluidly coupled to the internal cavity 230 at a third location with respect to the longitudinal axis A-A. Each of the first, second, and third locations are different, and may be spaced from one another along the longitudinal axis A-A.

[0069] Subsequently, in step 430, a sample is added to the internal cavity 230. In step 440, a plurality of signals from the sensors 210 are read by the controller 300. In step 450, a density or fluid level of the sample is determined via the plurality of signals from the sensors 210. Optionally, the sensors 210 may be pressure sensors 210. Optionally, more than one density may be determined for different regions located between any two sensors as discussed above. In yet further optional configurations, the agitator 250 may be operated to increase or decrease agitation in response to the measured density in one or more different regions.

[0070] Alternative Slurry Density Measurement System and Related Method

[0071] FIGS. 9-24 show an alternative embodiment of a slurry density measurement system. The system generally includes a stirring device 500 generally similar to the stirring device with stir chamber 200 and agitator 250 operable to stir the slurry, as previously described herein. Reference is made to the prior description for details which is not repeated here in full for the sake of brevity. The following description of the present stirring device will focus on the differences in the two designs which are pertinent.

[0072] In contrast to stir chamber 200 of the prior stirring device, the stir chamber 502 of present stirring device 500 is configured differently in part for determining the density of the agricultural sample slurry in a different manner without use of pressure sensing ports 240 and related pressure sensing equipment. Instead, the present stirring device comprises a mechanically isolated stir chamber 502 configured to receive the agricultural sample slurry from grinder 110 and gently

agitate the slurry to keep the majority of agricultural solids (i.e. particles) in suspension for purposes of obtaining slurry density and other related measurements. The sample slurry may be a soil slurry in one non-limiting embodiment.

**[0073]** The present mechanically isolated stir chamber 502 is formed by a section of the stirring device housing that is mechanically isolated from other portions of the stirring device and related appurtenances interfaced with the stir chamber such as the slurry inlet and outlet. Accordingly, the weight of the stir chamber is solely supported independently of other portions of the stirring device and related system by a load cell, such as without limitation a strain gauge 504 in one embodiment which is rigidly mounted to an available support structure. As further described herein, this allows an accurate weight of the stir chamber 502 to be measured empty and when filled with slurry; the difference representing the weight of the volume of slurry in the chamber. This information is used in conjunction with other measurements described below to determine the overall density of the slurry and water/solids ratio of the slurry.

**[0074]** Referring now in general to FIGS. 9-24, present stirring device 500 generally comprises a vertically elongated partially hollow housing 510 which may include an upper housing section 511 and lower housing section 512. Upper housing section 511 mounts and supports the agitator mechanism including agitator 250 driven by motor 225 and gear train 251, as previously described herein. In the present embodiment, however, the agitator may include only a single rotatable agitator shaft 252 and blade 253 assembly which is supported from above by upper housing section 511 in an overhead suspended manner as shown. It bears noting that two shaft and blade assemblies may be used in alternative embodiments if necessary for adequate agitation of the slurry to keep solid in suspension depending on the nature of the slurry. The agitator shaft is supported by the upper housing section of the stirring device independently of the stir chamber. In some embodiments, the agitator shaft 252 and blade 253 may be directly driven by the motor such that the gear train may be omitted.

**[0075]** Although the mode of agitation disclosed uses a single agitator shaft and blade assembly hanging down into the stir chamber 502 from upper housing section 511, other modes of agitating the slurry may be used in other embodiments, including for example but not limited to pneumatic agitation (bubbling air up into the internal cavity 530 of the stir chamber through the slurry), and recirculating the sample slurry through a separate pumped slurry flow loop.

[0076] Lower housing section 512 defines the stir chamber 502 which includes internal cavity 530 configured for holding a volume of coarsely filtered slurry (or filtrate) received from grinder 110. Agitator shaft 252 and blade 253 assembly is positioned inside internal cavity 530, but not supported in any manner by the lower housing section 512. Upper housing section 511 provides sole support for the agitator shaft and blade assembly which enters the open top end 531 of the stir chamber internal cavity. Stir chamber 502 further includes a slurry inlet port 540 proximate to the top end of internal chamber 530 and a waste port 543 at the bottom or floor 530a of internal cavity 530.

[0077] Notably, the stir chamber 502 defined by lower housing section 512 may be mechanically isolated from the upper housing section 511 in one embodiment via an isolation air gap 506 formed therebetween. An annular isolation air gap 508 may also be provided to also mechanically isolate the slurry inlet conduit 541 (e.g., section of piping or tubing) from the slurry inlet port 540 of the stir chamber. This prevents any support of the stir chamber by the slurry inlet conduit. The inlet conduit may be rigid in construction and could otherwise adversely affect obtaining an accurate stir chamber weight measurement by strain gauge 504. A slip joint may be used for the slurry inlet connection which incorporates the annular isolation air gap 508 as shown. The slurry inlet conduit is supported independently from the stir chamber 502 via a separate mounting bracket 541a attached to an available support structure.

[0078] Lower housing section 512 includes a support bracket 505 configured to fixedly couple the lower housing section (i.e. stir chamber) to one end 504a of the strain gauge 504 in a cantilevered manner as shown. Support bracket 505 may be mounted to one lateral side of the lower housing section. The opposite end 504b of the strain gauge is fixedly coupled to an available support structure, which in one embodiment may be provided by a portion of bracket 507 rigidly coupled to upper housing section 511. Other available support structures may be used to coupled end 504b of strain gauge configured 504 thereto which are not connected to the upper housing section. The strain gauge 504 may have a horizontally elongated structure as shown in one embodiment. Mechanical fasteners such as threaded fasteners in one non-limiting embodiment may be used to couple the strain gauge to bracket 507 and lower housing section 512 (i.e. stir chamber). Other types of mechanism fasteners such as rivets, clamps, etc. may be used. Other types of load sensors operable to measure the weight (mass) of the stir chamber and able to structurally support the stir

chamber independently of the stirring device upper housing section in the manner described herein may be used.

[0079] It bears noting that the strain gauge readings are sensitive to forces and vibration coming from outside the sample slurry stir chamber 502. Mechanically isolating the stir chamber 502 from the rest of the stirring device via the isolation air gap 506 previously described herein prevents or minimizes such disturbances. In addition, any wires, flow conduits (tubing, piping, etc.) or other appurtenances that must still be connected to the sample chamber are preferably strain relieved nearby (i.e. self supported without reliance on the stir chamber for support) so that they cannot support or “push” or “pull” on the stir chamber system in any manner which could adversely affect accurate slurry weight/mass measurements by strain gauge 504. An example of this is slurry inlet mounting bracket 541a previously described herein. These support measures external to the stir chamber help ensure the accuracy of the strain gauge weight/mass measurements.

[0080] The load cell (e.g., strain gauge 504) is used to measure the weight (mass) of the slurry inside the stir chamber by determining the differential weight between an empty stir chamber and then again when filled with slurry; the difference representing the weight of the slurry alone. To determine the density of the slurry, the volume of slurry must also be determined (density being a measure of the mass per unit volume of material). In one embodiment, a level sensor 515 may be provided to determine the volume of slurry in stir chamber 502.

[0081] Level sensor 515 may be a non-contact type level sensor in one embodiment such as a ultrasonic transducer or similar; however, other type level sensors including contact level sensors could be used if appropriate. Sensor 515 may be mounted to upper housing section 511 and has a line of sight directly into internal cavity 530 of the stir chamber 502 through the open top end to of the chamber in order to detect a surface level of the slurry, which is correlated to the height of the column of slurry in the stir chamber via controller 300. Since the dimensions of the stir chamber internal cavity 530 are precisely known, the volume of slurry held therein at any given time can be readily determined as a function of the height of the column of slurry present. This information can be preprogrammed into controller 300 for use in determining the volume of slurry based on the slurry level detection (height of slurry column).

[0082] The accuracy and repeatability of the volume measurements via level sensor 515 is dependent on the cleanliness of the sensor. So the sensor in one embodiment is preferably mounted in upper housing section 511 of stirring device 500 as far removed from the surface of the liquid

slurry in the stir chamber 502 as possible to avoid being splashed when the slurry is agitated. In one embodiment, a downwardly open sensor cavity 515a recessed into the bottom of upper housing section 511 may be provided to maximize the distance of the sensor from the surface level of the sample slurry.

**[0083]** The density of the slurry can be determined by dividing the total mass of slurry (weight) measured via strain gauge 504 by the volume of slurry determined via level sensor 515. In one embodiment, the density can be calculated automatically by programmable controller 300 shown in the modified system block diagram of FIG. 9. Strain gauge 504 and level sensor 515 are operably and communicably linked to controller 300, which is programmed with the appropriate program instructions (e.g., control logic) to calculate the density of the slurry based on the measured weight (mass) and calculated volume of the slurry based on slurry level measurement.

**[0084]** In one embodiment, a method for automatically determining density of the agricultural sample slurry via controller 300 may comprise the following steps implemented by the controller.

**[0085]** First, the controller 300 measures the weight of the stir chamber 502 in an empty condition any time before the start of a sample slurry processing run without slurry present in the chamber. This provides a first empty stir chamber weight. Next, an amount (volume) of slurry is added to the stir chamber (e.g., internal cavity 530) via slurry inlet port 540, such as from the grinder 110 as shown in FIG. 9. This may be done via controller opening isolation valve 525 (or manually) in the flow conduit between grinder 110 and stir chamber 502 (represented by the solid flow arrows). Valve 525 is then closed to fluidly isolate the grinder from the stir chamber and controller 300. The controller measures the weight of stir chamber 502 with slurry filled in the internal cavity 530. This provides a second filled stir chamber weight. The slurry may be agitated via agitator 250 before or after the measurements is taken, but preferably not during slurry weight and level measurements.

**[0086]** Next, the controller next calculates/determines the actual weight of the slurry by comparing and subtracting the empty stir chamber weight from the filled stir chamber weight. This represents the mass of slurry present in the stir chamber. It bears noting that the mass of slurry added to the stir chamber 502 may initially be unknown. The weight of the slurry is determined by controller 300 based on the actual volume of slurry present in the stir chamber 502.

**[0087]** Controller 300 also automatically determines the volume of sample slurry present in stir chamber 502 via level sensor 515, either before, after, or simultaneously with the step of

determining the mass (weight) of the slurry. Level sensor 515 is activated by the controller to measure the level of the slurry in stir chamber 502.

**[0088]** Controller 300 has been preprogrammed with data related to the volume of slurry present in stir chamber internal cavity 530 as a function of the height of the slurry column represented by the slurry level measurement, such as via a lookup table or appropriate equation. The controller executes a routine to readily correlate the level of the slurry measured in real-time (via detecting the top surface of the slurry) to a corresponding representative volume of slurry present based on the height of the slurry column detected. It is well within the ambit of those skilled in the art to program the controller with the appropriate data and software instructions to make the correlation between measured slurry surface level and volume.

**[0089]** Finally, with both the slurry mass and volume parameters determined, controller 300 calculates the overall density of the slurry based on the slurry weight/mass and slurry level measurements obtained by the strain gauge and level of the entire slurry sample in stir chamber 502. This recognizes that the slurry is not an ideally homogenous mixture, so that measuring the entire slurry sample averages out areas of lower or higher density in the slurry mass. It bears noting that the slurry weight and level measurements are preferably performed when the agitator 250 is not in operation so that the slurry is in a still and stable condition. This is desirable to ensure that accuracy for the slurry level detection and the weight/mass measurements. The forces exerted by the agitator, the sloshing of the sample slurry, and the body of the agitator itself could shift these measured values rendering them inaccurate.

**[0090]** According to another aspect, stirring device 500 further includes a spectrometer 550 to determine the water/solids ratio of the agricultural sample slurry. Spectrometer 550 is operably coupled to programmable controller 300 as shown in FIG. 9. The spectrometer may be mounted proximate to the bottom end of stir chamber 502, and in one non-limiting embodiment as illustrated may be mounted on the underside the chamber to maximize the spectrometer's exposure to heavier-than-water particles in the sample slurry, which tend to settle to the bottom of the chamber. Spectrometer 550 comprises a lens 551 fluidly sealed to stir chamber 502 to give the spectrometer a line of sight directed upwards into internal cavity 530 of the stir chamber.

**[0091]** The spectrometer 550 is configured and operable to measure reflectivity of the sample slurry in the stir chamber. More particularly, spectrometer 550 in one aspect is operable for measuring particle density (grams per milliliter) of the solids in the slurry. Based on the reflectivity

measurement of the sample solids in stir chamber 502, physical properties of the sample material can be determined, including the density of the solids (particles) in suspension in the sample slurry. Knowing the density of the water ( $\approx 0.998$  mL/g) and the measured density of the solids particles (e.g., soil or other) in suspension, controller 300 may be programmed to automatically calculate the water/solids ratio. The soil particle density can be predicted and correlated to the reflectivity measurements of the sample via experimental methods, which is well within the ambit of those skilled in the art. This information can form the basis for programming controller 300 to make the correlation between reflectivity and particle density automatically.

**[0092]** Accordingly, using the slurry sample's particle density measured by spectrometer 550 obtained from several reflectivity measurements and the density of the sample slurry determined by controller 300 discussed above, the current actual ratio of water mass to sample solids (particles) mass in the sample slurry (e.g., water/solids) can further be determined by controller 300 based on the reflectivity readings. Based on the real-time or actual current ratio, the controller 300 will automatically adjust the sample slurry in stir chamber 502 as needed until the desired target water/solids ratio has been reached which is optimized for analysis of the sample in the chemical/property analysis unit 140 of the system (see, e.g., FIG. 9). This includes adding more water to dilute the slurry, or more slurry to increase the amount of solids in suspension in the slurry. The solids may be soil for a soil sample, or any other agricultural or farm-related solid to be analyzed by the system.

**[0093]** One non-limiting embodiment of the process implemented by controller 300 to achieve the desired target water/solids ratio (i.e. mass ratio) based on reflectivity measurements collected by spectrometer 550 may include but is not limited to the following control steps. Step (1): Determining a real-time or actual current water/solids ratio based on reflectivity measurements of the sample recorded by spectrometer 550. Step (2) Comparing the actual water/solids ratio to a preprogrammed target water/solids ratio for the sample slurry. Step (3) Adjusting the actual water/solids ratio to meet the target water/solids ratio. For example, if the actual water/solids ratio is less than the target water/solids ratio, controller 300 adds water to the stir chamber 502 (via slurry inlet port 540, a separate water inlet port, or a slurry recirculation inlet port) and repeating steps (1) and (2) one or more times until the controller 300 determines that the target water/solids ratio in the sample slurry is met. For example, the controller will initiate a process to add water to stir chamber 502 if the actual current water/solids ratio is less than the target ratio (i.e. more

dilution water is needed in the slurry). Conversely, if the actual current water/solids ratio is greater than the target, more slurry (with entrained solids) is needed to reduce the water dilution of the slurry and increase its solids content. So controller 300 may briefly open isolation valve 525 to add an additional amount of slurry from grinder 110 into stir chamber 502. Steps (1) and (2) are again repeated as needed until the target ratio is met.

**[0094]** A predetermined +/- variance in the target water/solids ratio may be programmed into controller 300 in some embodiments when permissible so that a measured actual water/solids ratio may be considered to meet the target water/solids ratio for purposes of the sample analysis if not greater or less than a programmed tolerance percentage. Accordingly, an acceptable target range of water/solids ratio may be used by the controller in some embodiments in lieu of a single absolute value for the target ratio.

**[0095]** It bears noting that in certain embodiments, the pump 120 which takes suction for stir chamber 502 to transfer slurry to the analysis unit 140 may also be used to recirculate a portion of the sample slurry via recirculation line 120a along with adding water to the recirculated slurry from an external water source (see, e.g., FIG. 9) as the means to adjust (i.e. decrease) the water/solids ratio of the sample slurry in stir chamber 502.

**[0096]** The spectrometer 550 may also be used to identify other properties of the sample, including but not limited to soil structure (e.g., sand content), color profile, and organic matter content. By monitoring the reflectance of the sample at various levels of agitation, properties of fractions of the sample can also be measured (e.g., stop agitating the sample and let heavy particles settle downward onto the lens 551 of the spectrometer).

**[0097]** Once the desired target mass ratio of water to solids for the slurry has been reached, the sample slurry is ready for chemical analysis. Stirring device 500 includes a vertically-extending filtrate suction tube 521 through which pump 120 (a slurry pump in one embodiment) can extract slurry from the internal cavity 530 of stir chamber 502 via one or more filtrate outlet ports 520. In one embodiment, plural outlet ports may be provided which are fluidly coupled to the vertical suction tube 521 via a branched flow manifold 521a as shown. The use of multiple smaller filtrate outlet ports allows several samples to be drawn simultaneously from stir chamber 502 for different portions of the analysis unit to test for different analytes at the same time in parallel. In other embodiments, a single larger filtrate outlet port may be used instead. The filtrate outlet ports 520 may be disposed in the upper housing section 511 of the stirring device and may extend laterally

through the upper housing section (see, e.g., FIGS. 22-23) as shown. The filtrate suction tube 521 is suspended from the upper housing section 511 such that the weight of the tube is preferably supported solely by the upper housing section alone. This support configuration does not add to weight of the stir chamber when weighting the slurry via strain gauge 504, as described elsewhere herein. In other possible embodiments, the filtrate outlet ports 520 could instead be disposed in the sidewall of the lower housing section 512 (stir chamber 502) such that the filtrate suction tube 521 would then be supported by the stir chamber and its weight taken into account when weighing the slurry.

**[0098]** There may be particles in the sample slurry however that are too large in size to be tolerated by the small openings and flow conduits within the analysis unit 140. This could cause issues such as plugging/blockages in the downstream analysis equipment. Accordingly, a combination of filtration and separation features/measures may be implemented in stir chamber 502 to prevent the largest particles (solids) which could cause problems from leaving the chamber and entering the analysis equipment.

**[0099]** In one embodiment, the filtration feature may comprise a slurry secondary filter 522 (grinder 110 acting as the primary filter for large particle separation). Filter 522 is disposed upstream of pump 120 in the slurry flow circuit shown in FIG. 9. In one embodiment, the filter 522 may be disposed inside stir chamber 502, and may be coupled to the filtrate suction tube 521 inside the internal cavity 530 of the stir chamber. For example, filter 522 may be coupled to the bottom inlet end of suction tube 521 which hangs down from above into stir chamber internal cavity 530 and is suspended above the bottom of the cavity (see, e.g., FIG. 22). In one embodiment, filter 522 may be a mesh filter comprising a mesh screen having a plurality of mesh openings sized to prevent solid particles exceeding a predetermined maximum size from being drawn into the filtrate suction tube 521 and passing downstream. Accordingly, the size of the screen openings of such a filter are sized in proportion to the smallest flow passage of the analysis equipment of analysis unit 140 to not pass particles exceeding the smallest flow passage size (e.g., diameter).

**[0100]** The separation feature comprises limiting the rotational speed of the agitator 250 so that the heaviest (largest) particles in the sample slurry are not lifted high enough in the slurry column to be drawn toward and onto the secondary filter 522, which is located and suspended by a vertical distance above the floor or bottom of the stir chamber in internal cavity 530. This could otherwise

result in frequent plugging of the small mesh screen openings of the filter. Agitation is still necessary to promote chemical homogeneity in the sample, but limited to agitate the slurry gently enough to therefore leave large and chemically irrelevant particles below the secondary filter at the bottom of the stir chamber. Accordingly, agitator 250 has a maximum rotational speed selected to keep sample solids large particles at the bottom of the stir chamber 502, which prevents the large particles from being drawn to the secondary filter 522. In other words, the agitator is configured and operable to stir the slurry via the blade 253 at a maximum speed selected so that at least some larger particles drop out of suspension from the slurry and collect at a bottom of the internal cavity 530 of the stir chamber.

**[0101]** To further help keep the slurry solids particles from being drawn onto filter 522, the bottom or floor 530a of stir chamber internal cavity 530 may be sloped from side to side such that the portion of the floor beneath the filter may be lower than the portion of the floor beneath the agitator blade 253 (see, e.g., FIG. 21). This deeper portion of stir chamber internal cavity 530 beneath the filtrate suction tube 521 and filter 522 forms a recess or pocket in which larger particles can settle out of suspension and collect without being drawn upwards towards the filter 522. In addition, waste port 543 may be coupled to this deeper portion of the stir chamber internal cavity 530 beneath the filter 522 to more effectively flush residual solids out with water between slurry processing runs. Accordingly, the sloped floor 530a of stir chamber 502 provides multiple functions and benefits.

**[0102]** In some embodiments, a vacuum sensor 523 may be disposed upstream of pump 120 between secondary filter 522 and the pump to allow for the detection of a clogged secondary filter screen. In one embodiment, vacuum sensor 523 may be fluidly coupled to and disposed on the filtrate suction tube 521 on the downstream filtrate side of secondary filter 522. The vacuum sensor may be operable coupled to programmable controller 300 to provide automatic detection of a plugged/clogged filter 522 by the controller. The controller may then terminate slurry extraction from stir chamber 502 by stopping operation of pump 120 until the clogged filter can be cleaned. In other embodiments, vacuum sensor 523 may be fluidly coupled to the flow conduit 120b between pump 120 and stir chamber 502 (reference FIG. 9).

**[0103]** In alternative embodiments, pump 120 may be omitted altogether and the slurry filtrate may flow via gravity from stir chamber 502 to analysis unit 140 for processing and analysis for various analytes or other relevant properties of the agricultural sample.

[0104] The agricultural sample slurry preparation system including grinder-filter apparatus 110 and waste collection system including waste collection apparatus 160 disclosed herein is usable with and may form part of an overall agricultural sampling and analysis systems, such as but not limited to those described in U.S. Patent Application Publication No. 2018/0124992A1 and PCT Publication No. WO2020/012369, and other systems are described in U.S. Application Nos. 62/983237, filed on 28 February 2020; 63/017789, filed on 30 April 2020; 63/017840, filed on 30 April 2020; 63/018120, filed on 30 April 2020; 63/018153, filed on 30 April 2020; 63/191159, filed on 20-May-2021; 63/191166, filed on 20-May-2021; 63/191172, filed on 20-May-2021; 17/326050, filed on 20-May-2021; 63/191186, filed on 20-May-2021; 63/191189, filed on 20-May-2021; 63/191195, filed on 20-May-2021; 63/191199, filed on 20-May-2021; 63/191204, filed on 20-May-2021; 17/343434, filed on 09-Jun-2021; 63/208865, filed on 09-Jun-2021; 17/343536, filed on 09-Jun-2021; 63/213319, filed on 22-Jun-2021; 63/260772 filed on 31-Aug-2021; 63/260776 filed on 31-Aug-2021; 63/260777 filed on 31-Aug-2021, 63/245278 filed on 17-Sept-2021; 63/264059 filed on 15-Nov-2021; 63/264062 filed on 15-Nov-2021; 63/264065 filed on 15-Nov-2021; and 63/369722, filed 28 July 2022; 63/369724, filed 28 July 2022; 63/369765, filed 28 July 2022; 63/369988, filed 01 August 2022; 63/489209, filed 09 March 2023; and 63/507,517, filed 12 June 2023; and PCT Application Nos. PCT/IB2021/051076, filed on 10 February 2021; PCT/IB2021/051077, filed on 10 February 2021; PCT/IB2021/052872, filed on 07 April 2021; PCT/IB2021/052874, filed on 07 April 2021; PCT/IB2021/052875, filed on 07 April 2021; PCT/IB2021/052876, filed on 07 April 2021; PCT/IB2023/050081, filed 5 January 2023; PCT/IB2023/050082, filed 5 January 2023; PCT/IB2023/050730, filed 27 January 2023; PCT/IB2023/050901, filed 2 February 2023; PCT/IB2023/051626, filed 22 February 2023; PCT/IB2023/051627, filed 22 February 2023; PCT/IB2023/052204, filed 08 March 2023; PCT/IB2023/052205, filed 8 March 2023; PCT/IB2022/058401, filed 7 September 2022; PCT/IB2022/058402, filed 7 September 2022; and PCT/IB2022/058408, filed 7 September 2022.

## EXAMPLES

[0105] The following are nonlimiting examples.

[0106] Example 1 - a stirring device for processing an agricultural slurry comprising: a stir chamber comprising an upper housing section and a lower housing section defining an internal cavity configured to receive an agricultural sample slurry; a strain gauge structurally coupled to and independently supporting the stir chamber, the strain gauge configured and operable to

measure a weight of the stir chamber with and without slurry therein; wherein the stir chamber is mechanically isolated from other portions of the stirring device.

[0107] Example 2 - the stirring device according to Example 1, wherein the lower housing section is mechanically isolated from the upper housing section by an isolation air gap formed therebetween.

[0108] Example 3 - the stirring device according to Example 2, wherein the stir chamber is supported in a cantilevered manner by the strain gauge.

[0109] Example 4 - the stirring device according to any one of Examples 1-3, further comprising a level sensor disposed in the upper housing section, the level sensor being operable to measure a level of the slurry.

[0110] Example 5 - the stirring device according to Example 4, wherein the level sensor is a non-contact type level sensor having a line of sight into the stir chamber to detect the level of the slurry.

[0111] Example 6 - the stirring device according to Examples 4 or 5, further comprising a spectrometer mounted to the stir chamber, the spectrometer being operable to measure reflectivity of solids in the slurry in the stir chamber.

[0112] Example 7 - the stirring device according to Example 6, wherein the spectrometer is mounted proximate to a bottom end of the stir chamber and comprises a lens sealed to the stir chamber, the spectrometer having a line of sight into the stir chamber.

[0113] Example 8 - the stirring device according to Example 6, further comprising a programmable controller operably coupled to the strain gauge, level sensor, and spectrometer, the controller being configured to determine a density of the sample slurry based on measurements obtained by the strain gauge and level sensor.

[0114] Example 9 - the stirring device according to Example 8, wherein the controller is configured to determine a water mass to solids mass ratio of the slurry via the reflectivity of the solids in the slurry measured by the spectrometer.

[0115] Example 10 - the stirring device according to any one of Examples 1-9, wherein the strain gauge is supported from the upper housing section via a bracket.

[0116] Example 11 - the stirring device according to Example 10, wherein the strain gauge comprises a first end coupled to the lower housing section and a second end coupled to the upper housing section by a bracket.

[0117] Example 12 - the stirring device according to Examples 2 or 3, wherein the stir chamber further comprises a slurry inlet port which is fluidly isolated from a slurry inlet conduit by an annular isolation air gap.

[0118] Example 13 - the stirring device according to Examples 2 or 3, wherein the stir chamber further comprising a vertically-extending filtrate suction tube configured to extract slurry from the internal cavity through one or more filtrate outlet ports of the stirring device.

[0119] Example 14 - the stirring device according to Example 13, wherein the one or more filtrate outlet ports are disposed in the upper housing section of the stirring device, and the filtrate suction tube is suspended in the internal cavity of the stir chamber from the upper housing section.

[0120] Example 15 - the stirring device according to Examples 13 or 14, wherein the filtrate suction tube extends vertically from at least a top end of the stir chamber down into a lower portion of the internal cavity of the stir chamber.

[0121] Example 16 - the stirring device according to any one of Examples 13-15, wherein the filtrate suction tube is fluidly coupled to a pump via the filtrate outlet ports, the pump operable to apply suction to the filtrate suction tube for extracting the slurry from the stir chamber.

[0122] Example 17 - the stirring device according to Example 16, further comprising a filter fluidly coupled to the filtrate suction tube inside the internal cavity of the stir chamber to filter the slurry.

[0123] Example 18 - the stirring device according to Example 17, wherein the filter comprises a mesh screen having openings sized to prevent solid particles exceeding a maximum size from being drawn into the filtrate suction tube.

[0124] Example 19 - the stirring device according to Examples 17 or 18, further comprising a vacuum sensor disposed upstream of the pump between the pump and the filter, the vacuum sensor operable to detect a vacuum condition which is indicative of a clogged condition of the filter.

[0125] Example 20 - the device according to any one of Examples 1-19, further comprising an agitator including a rotatable agitator shaft with blade disposed in the internal cavity of the stir chamber and a motor operably coupled to the agitator shaft, the agitator shaft being supported by the upper housing section of the stirring device independently of the stir chamber.

[0126] Example 21 - the device according to Example 20, wherein the agitator is configured and operable to stir the slurry via the blade at a maximum speed selected so that at least some particles

drop out of suspension from the slurry and collect at a bottom of the internal cavity of the stir chamber.

[0127] Example 22 - an agricultural slurry analysis system comprising: a stirring device comprising an upper housing section and a lower housing section defining a stir chamber configured to receive an agricultural sample slurry; a strain gauge coupled to the stir chamber, the strain gauge configured and operable to measure a weight of the stir chamber with and without slurry therein; a level sensor disposed in the upper housing section, the level sensor operable to measure a level of the slurry in the stir chamber; a programmable controller operably coupled to the strain gauge and level sensor, the controller being configured to: receive an actual weight measurement of the stir chamber via the strain gauge; determine a weight of the slurry in the stir chamber based on the actual weight measurement; receive an actual slurry level measurement from the level sensor; and determine a density of the slurry based on the actual weight measurement and the actual slurry level measurement.

[0128] Example 23 - the system according to Example 22, wherein the controller is configured to determine the weight of the slurry by receiving a first weight measurement of the stir chamber without the slurry therein, and a second weight measurement of the stir chamber with the slurry therein, the controller being configured to determine the weight of the slurry by subtracting the first weight measurement from the second weight measurement.

[0129] Example 24 - the system according to Example 23, wherein the controller is configured to correlate the actual slurry level measurement with a corresponding volume of slurry in the stir chamber.

[0130] Example 25 - the system according to Example 24, wherein the controller is operable to determine the density of the slurry by dividing the weight of the slurry by the volume of the slurry in the stir chamber.

[0131] Example 26 - the system according to any one of Examples 22-25, further comprising a spectrometer configured to measure a density of particles in suspension within the slurry, and the controller determining an actual water mass to soil mass ratio of the slurry based on the particle density measurement.

[0132] Example 27 - the system according to Example 26, wherein the spectrometer is configured to measure reflectivity of the particles to determine the density of the particles.

[0133] Example 28 - the system according to Examples 26 or 27, wherein the controller compares the actual water mass to soil mass ratio with a preprogrammed target water mass to soil mass ratio.

[0134] Example 29 - the system according to Example 28, wherein the controller is configured to initiate a process to add water to the stir chamber when the actual water mass to soil mass ratio is less than the target water mass to soil mass ratio.

[0135] Example 30 - the system according to any one of Examples 22-29, further comprising a pump configured to draw slurry from the stir chamber through a filter.

[0136] Example 31 - the system according to Example 30, further comprising a vacuum sensor operably coupled to the controller and disposed upstream of the pump in a slurry flow circuit, the vacuum sensor operable to detect a vacuum condition between the pump and filter which is indicative of a clogged filter.

[0137] Example 32 - the system according to Example 31, wherein the controller is operable to terminate operation of the pump upon detection of the vacuum condition.

[0138] While the foregoing description and drawings represent some example systems, it will be understood that various additions, modifications and substitutions may be made therein without departing from the spirit and scope and range of equivalents of the accompanying claims. In particular, it will be clear to those skilled in the art that embodiments of the present disclosure may be embodied in other forms, structures, arrangements, proportions, sizes, and with other elements, materials, and components, without departing from the spirit or essential characteristics thereof. In addition, numerous variations in the methods/processes described herein may be made. One skilled in the art will further appreciate that the embodiments of the present disclosure may be used with many modifications of structure, arrangement, proportions, sizes, materials, and components and otherwise, used in the practice of the embodiments of the present disclosure, which are particularly adapted to specific environments and operative requirements without departing from the principles of the present embodiments of the present disclosure. The presently disclosed embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the embodiments of the present disclosure being defined by the appended claims and equivalents thereof, and not limited to the foregoing description or embodiments. Rather, the appended claims should be construed broadly, to include other variants and embodiments, which may be made by those skilled in the art without departing from the scope and range of equivalents of the embodiments of the present disclosure.

## CLAIMS

What is claimed is:

1. A stirring device for processing an agricultural slurry comprising:  
a stir chamber comprising an upper housing section and a lower housing section defining an internal cavity configured to receive an agricultural sample slurry;  
a strain gauge structurally coupled to and independently supporting the stir chamber, the strain gauge configured and operable to measure a weight of the stir chamber with and without slurry therein;  
wherein the stir chamber is mechanically isolated from other portions of the stirring device.
2. The stirring device according to claim 1, wherein the lower housing section is mechanically isolated from the upper housing section by an isolation air gap formed therebetween.
3. The stirring device according to claim 2, wherein the stir chamber is supported in a cantilevered manner by the strain gauge.
4. The stirring device according to any one of claims 1-3, further comprising a level sensor disposed in the upper housing section, the level sensor being operable to measure a level of the slurry.
5. The stirring device according to claim 4, wherein the level sensor is a non-contact type level sensor having a line of sight into the stir chamber to detect the level of the slurry.
6. The stirring device according to claims 4 or 5, further comprising a spectrometer mounted to the stir chamber, the spectrometer being operable to measure reflectivity of solids in the slurry in the stir chamber.
7. The stirring device according to claim 6, wherein the spectrometer is mounted proximate to a bottom end of the stir chamber and comprises a lens sealed to the stir chamber, the spectrometer having a line of sight into the stir chamber.
8. The stirring device according to claim 6, further comprising a programmable controller operably coupled to the strain gauge, level sensor, and spectrometer, the controller being configured to determine a density of the sample slurry based on measurements obtained by the strain gauge and level sensor.

9. The stirring device according to claim 8, wherein the controller is configured to determine a water mass to solids mass ratio of the slurry via the reflectivity of the solids in the slurry measured by the spectrometer.
10. The stirring device according to any one of claims 1-9, wherein the strain gauge is supported from the upper housing section via a bracket.
11. The stirring device according to claim 10, wherein the strain gauge comprises a first end coupled to the lower housing section and a second end coupled to the upper housing section by a bracket.
12. The stirring device according to claims 2 or 3, wherein the stir chamber further comprises a slurry inlet port which is fluidly isolated from a slurry inlet conduit by an annular isolation air gap.
13. The stirring device according to claims 2 or 3, wherein the stir chamber further comprising a vertically-extending filtrate suction tube configured to extract slurry from the internal cavity through one or more filtrate outlet ports of the stirring device.
14. The stirring device according to claim 13, wherein the one or more filtrate outlet ports are disposed in the upper housing section of the stirring device, and the filtrate suction tube is suspended in the internal cavity of the stir chamber from the upper housing section.
15. The stirring device according to claims 13 or 14, wherein the filtrate suction tube extends vertically from at least a top end of the stir chamber down into a lower portion of the internal cavity of the stir chamber.
16. The stirring device according to any one of claims 13-15, wherein the filtrate suction tube is fluidly coupled to a pump via the filtrate outlet ports, the pump operable to apply suction to the filtrate suction tube for extracting the slurry from the stir chamber.
17. The stirring device according to claim 16, further comprising a filter fluidly coupled to the filtrate suction tube inside the internal cavity of the stir chamber to filter the slurry.
18. The stirring device according to claim 17, wherein the filter comprises a mesh screen having openings sized to prevent solid particles exceeding a maximum size from being drawn into the filtrate suction tube.

19. The stirring device according to claims 17 or 18, further comprising a vacuum sensor disposed upstream of the pump between the pump and the filter, the vacuum sensor operable to detect a vacuum condition which is indicative of a clogged condition of the filter.
20. The device according to any one of claims 1-19, further comprising an agitator including a rotatable agitator shaft with blade disposed in the internal cavity of the stir chamber and a motor operably coupled to the agitator shaft, the agitator shaft being supported by the upper housing section of the stirring device independently of the stir chamber.
21. The device according to claim 20, wherein the agitator is configured and operable to stir the slurry via the blade at a maximum speed selected so that at least some particles drop out of suspension from the slurry and collect at a bottom of the internal cavity of the stir chamber.
22. An agricultural slurry analysis system comprising:  
a stirring device comprising an upper housing section and a lower housing section defining a stir chamber configured to receive an agricultural sample slurry;  
a strain gauge coupled to the stir chamber, the strain gauge configured and operable to measure a weight of the stir chamber with and without slurry therein;  
a level sensor disposed in the upper housing section, the level sensor operable to measure a level of the slurry in the stir chamber;  
a programmable controller operably coupled to the strain gauge and level sensor, the controller being configured to:  
receive an actual weight measurement of the stir chamber via the strain gauge;  
determine a weight of the slurry in the stir chamber based on the actual weight measurement;  
receive an actual slurry level measurement from the level sensor; and  
determine a density of the slurry based on the actual weight measurement and the actual slurry level measurement.
23. The system according to claim 22, wherein the controller is configured to determine the weight of the slurry by receiving a first weight measurement of the stir chamber without the slurry therein, and a second weight measurement of the stir chamber with the slurry therein, the controller being configured to determine the weight of the slurry by subtracting the first weight measurement from the second weight measurement.

24. The system according to claim 23, wherein the controller is configured to correlate the actual slurry level measurement with a corresponding volume of slurry in the stir chamber.
25. The system according to claim 24, wherein the controller is operable to determine the density of the slurry by dividing the weight of the slurry by the volume of the slurry in the stir chamber.
26. The system according to any one of claims 22-25, further comprising a spectrometer configured to measure a density of particles in suspension within the slurry, and the controller determining an actual water mass to soil mass ratio of the slurry based on the particle density measurement.
27. The system according to claim 26, wherein the spectrometer is configured to measure reflectivity of the particles to determine the density of the particles.
28. The system according to claims 26 or 27, wherein the controller compares the actual water mass to soil mass ratio with a preprogrammed target water mass to soil mass ratio.
29. The system according to claim 28, wherein the controller is configured to initiate a process to add water to the stir chamber when the actual water mass to soil mass ratio is less than the target water mass to soil mass ratio.
30. The system according to any one of claims 22-29, further comprising a pump configured to draw slurry from the stir chamber through a filter.
31. The system according to claim 30, further comprising a vacuum sensor operably coupled to the controller and disposed upstream of the pump in a slurry flow circuit, the vacuum sensor operable to detect a vacuum condition between the pump and filter which is indicative of a clogged filter.
32. The system according to claim 31, wherein the controller is operable to terminate operation of the pump upon detection of the vacuum condition.

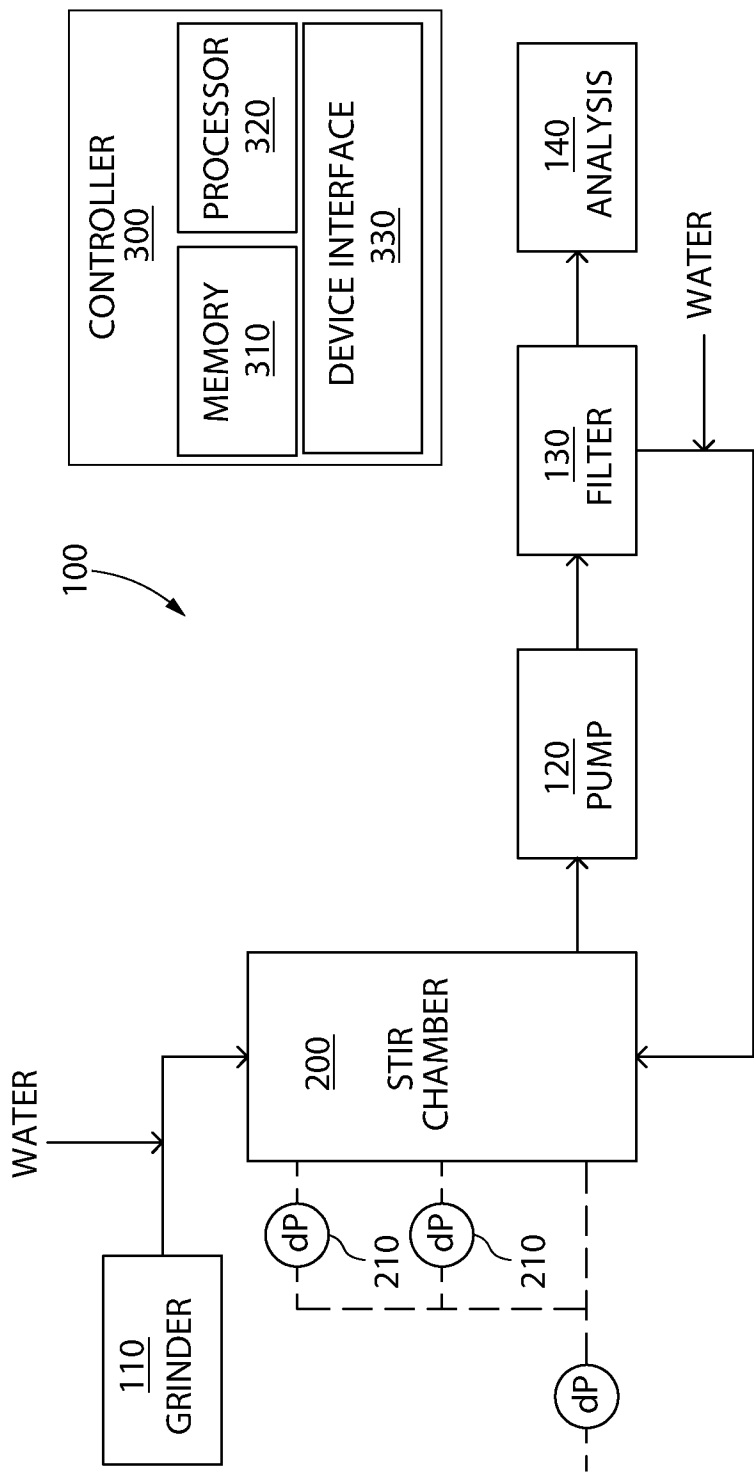


FIG. 1

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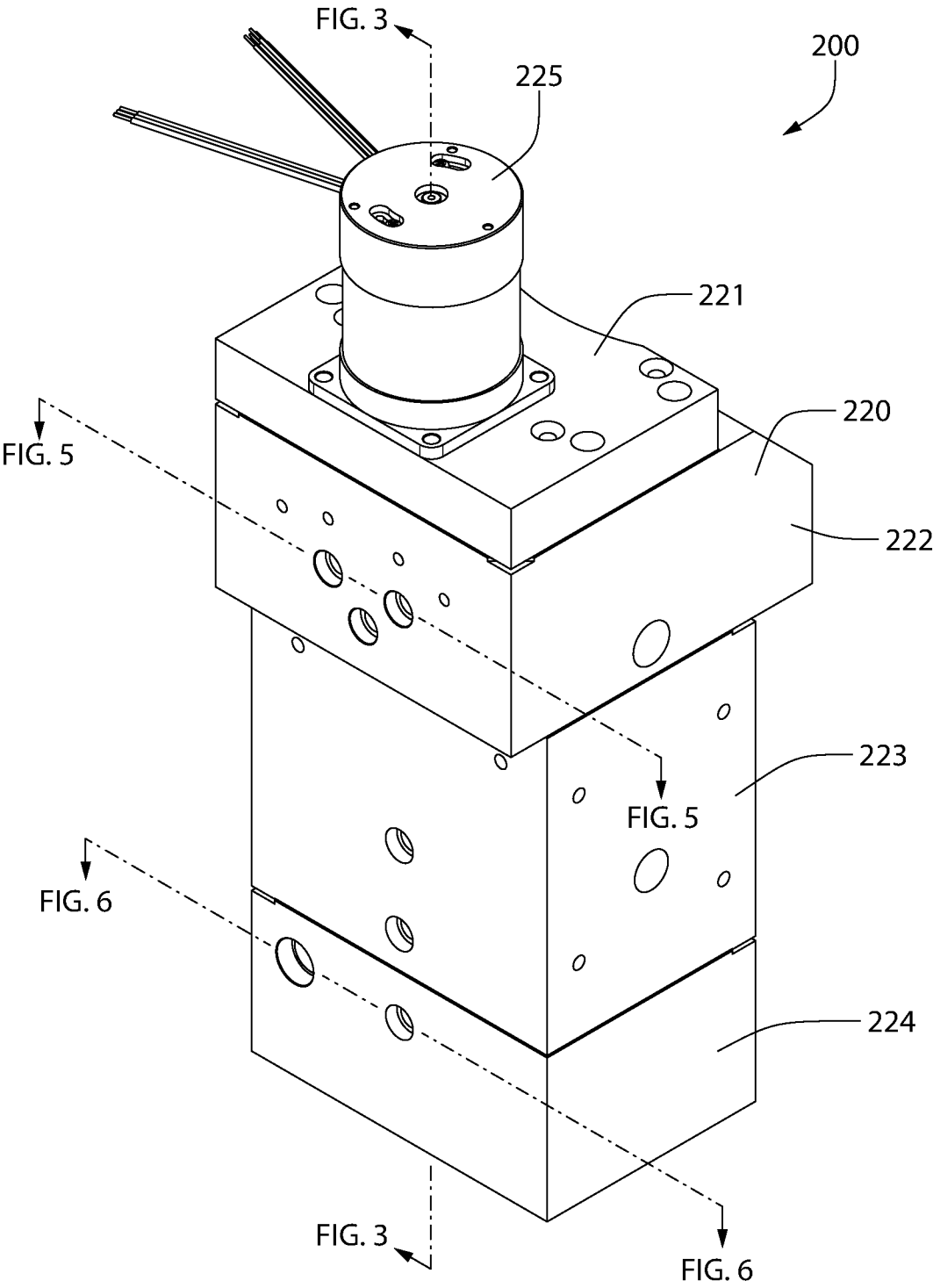


FIG. 2

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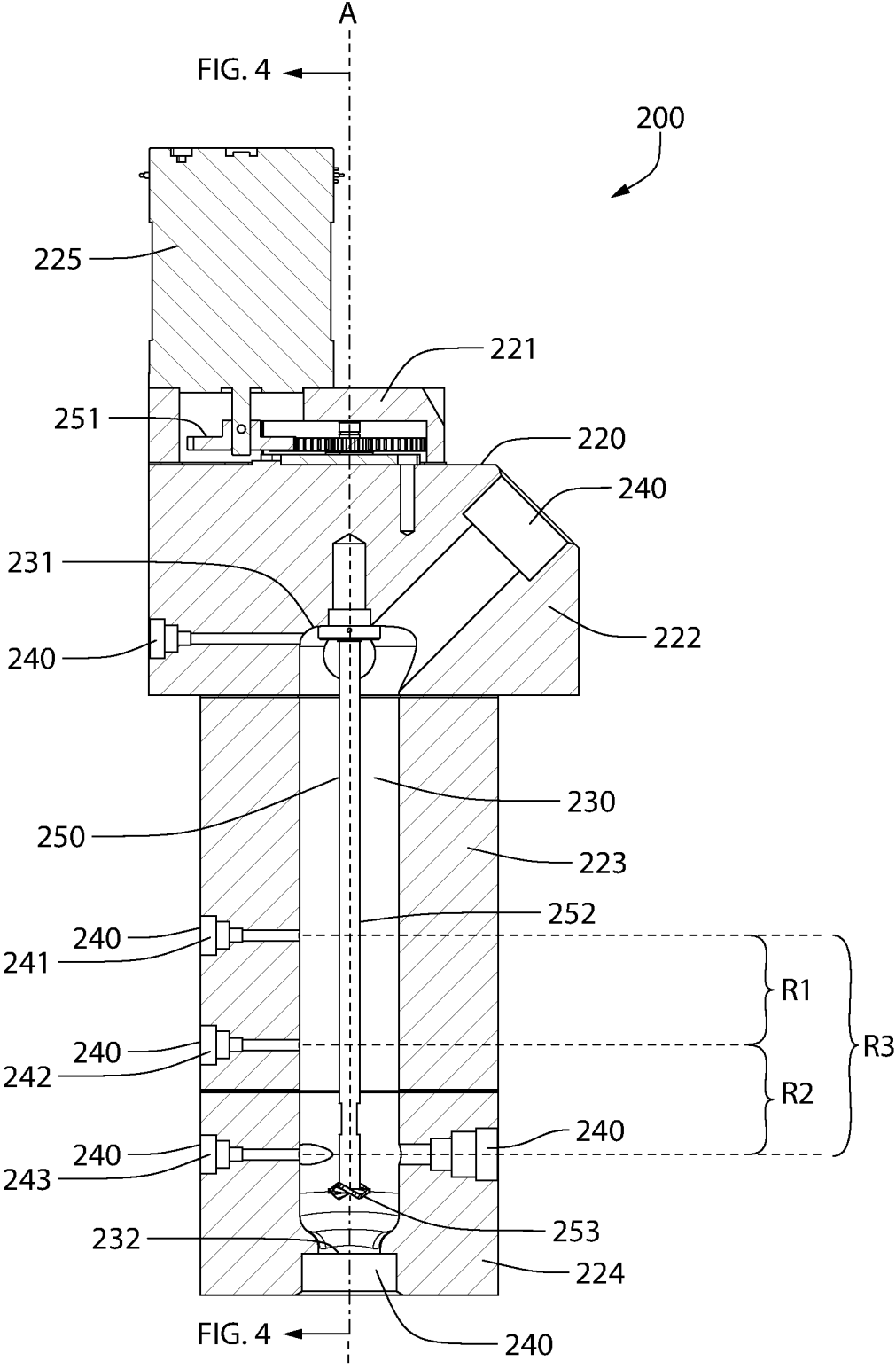


FIG. 3

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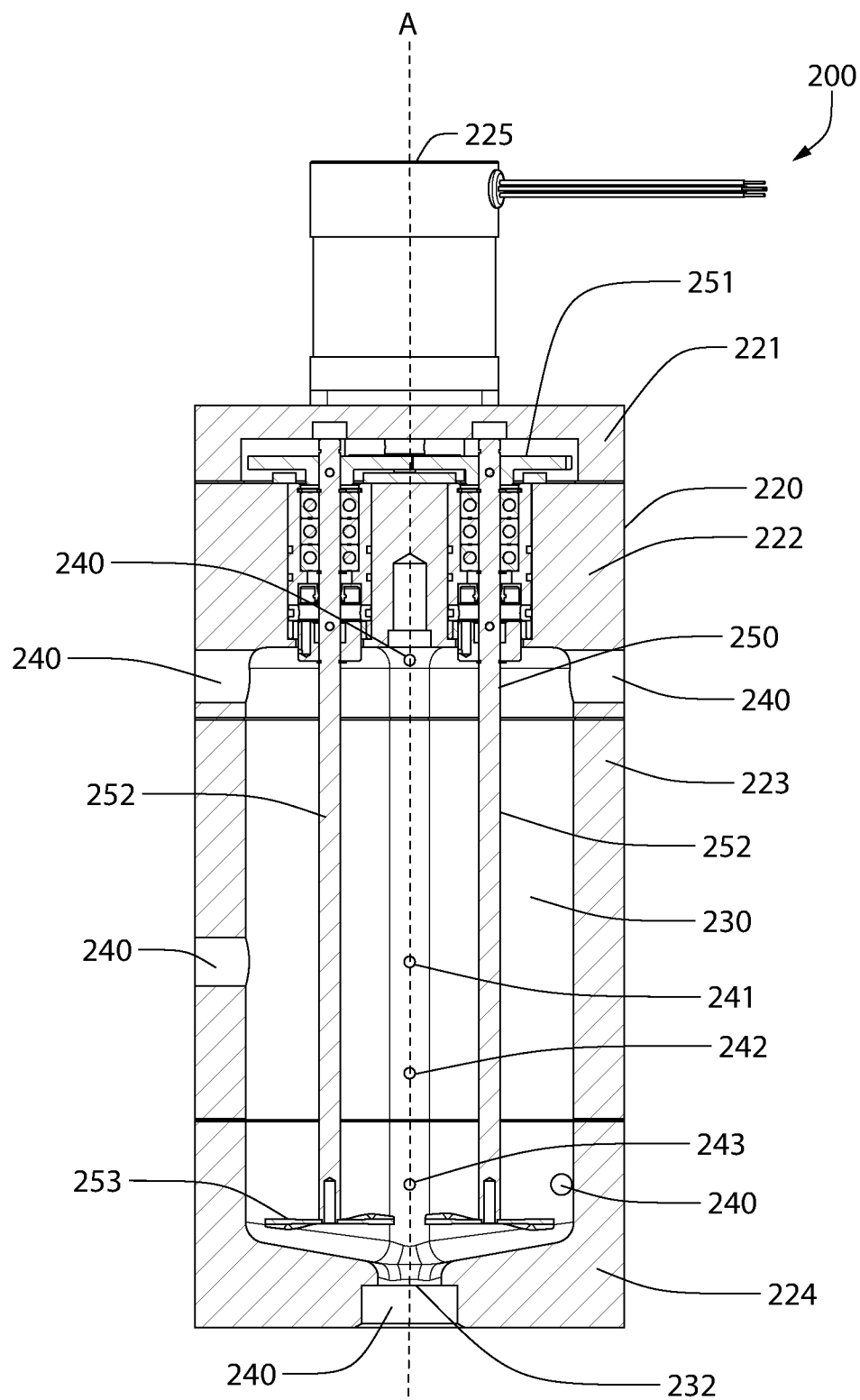


FIG. 4

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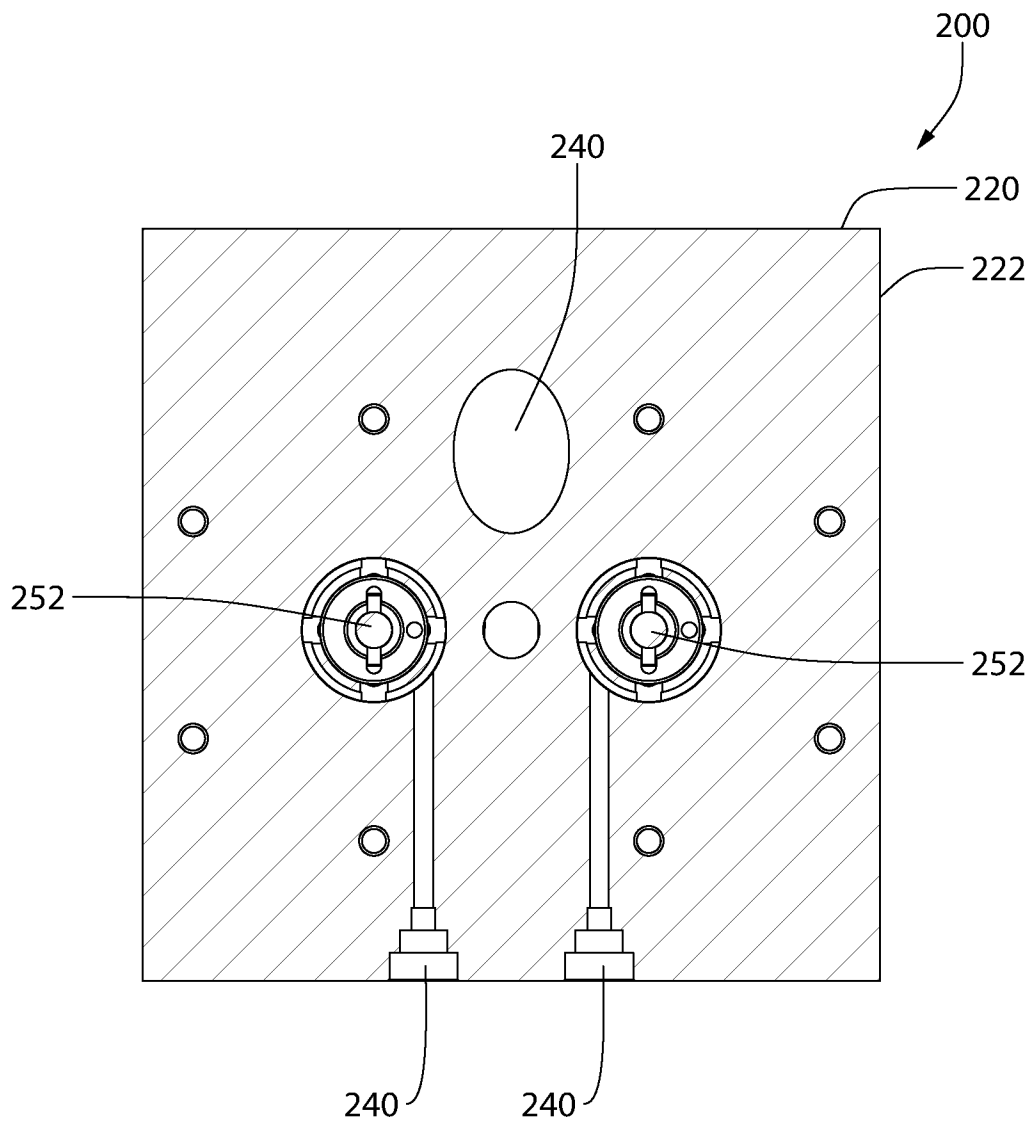


FIG. 5



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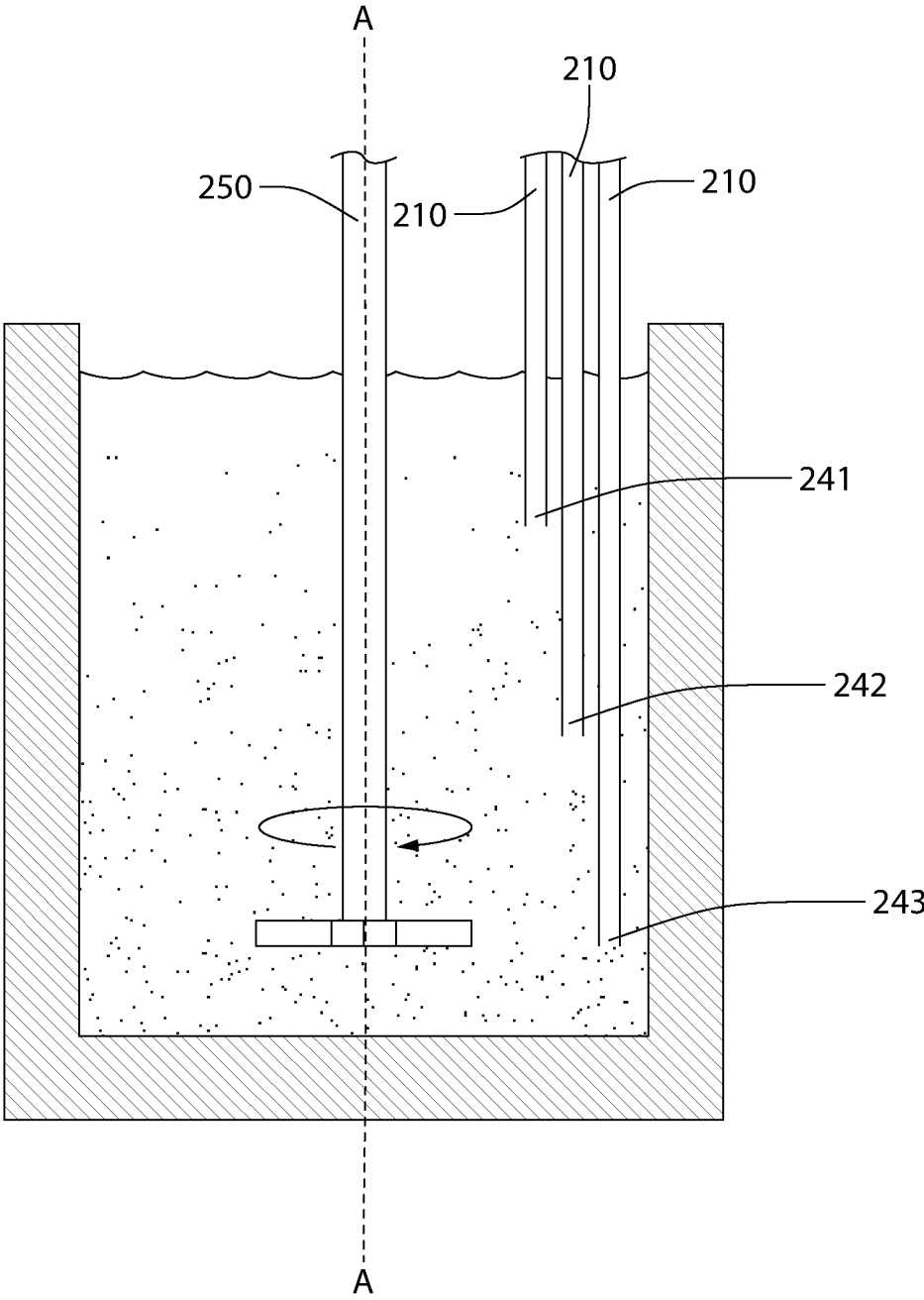


FIG. 7

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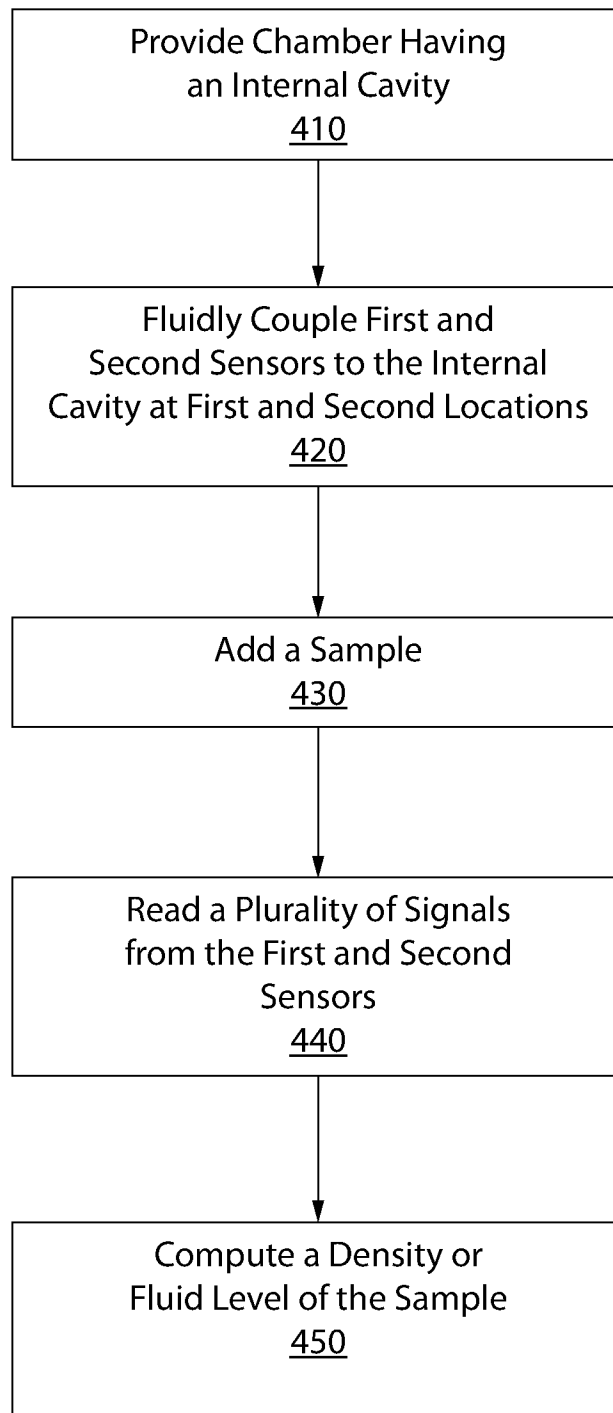


FIG. 8

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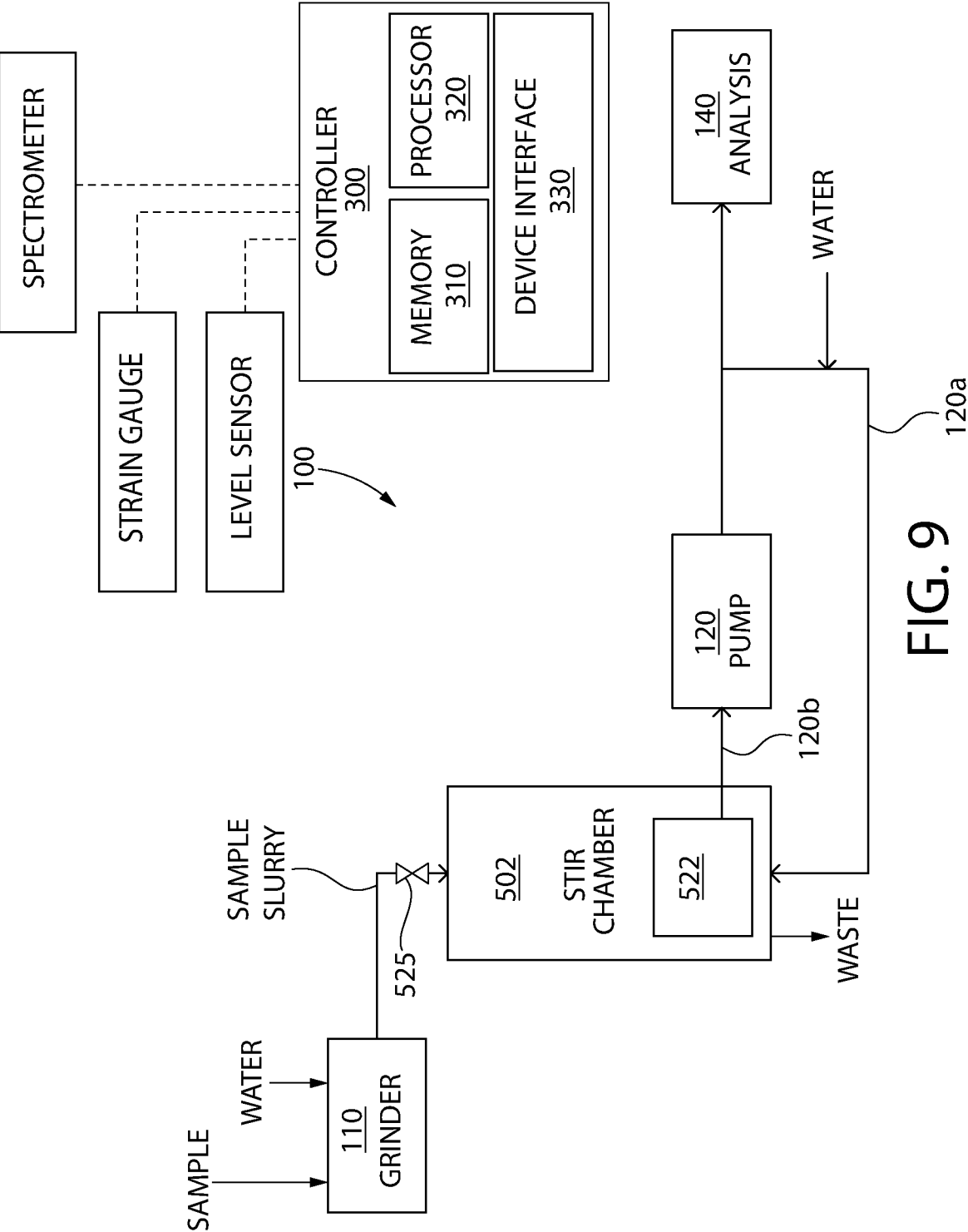


FIG. 9

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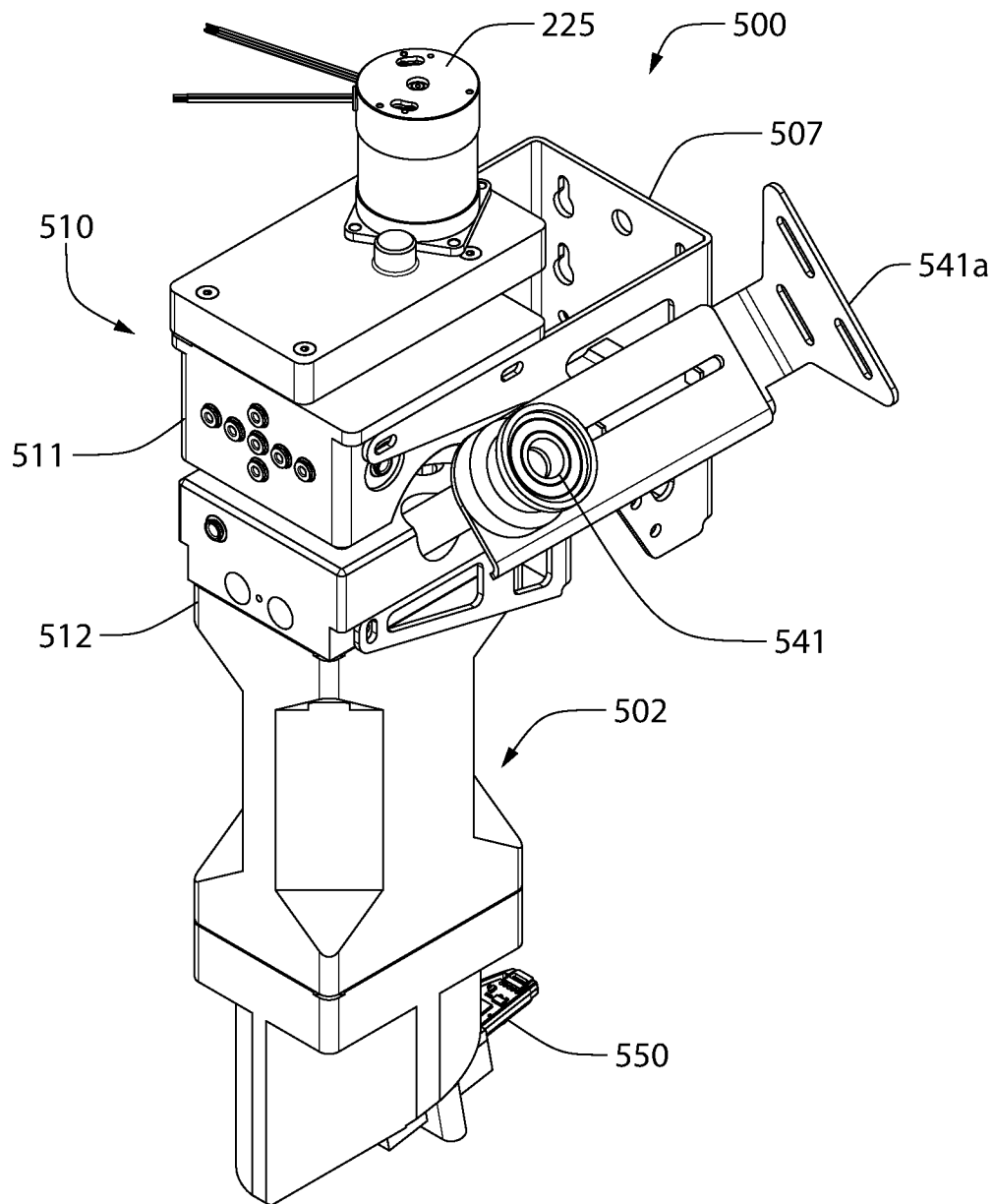


FIG. 10

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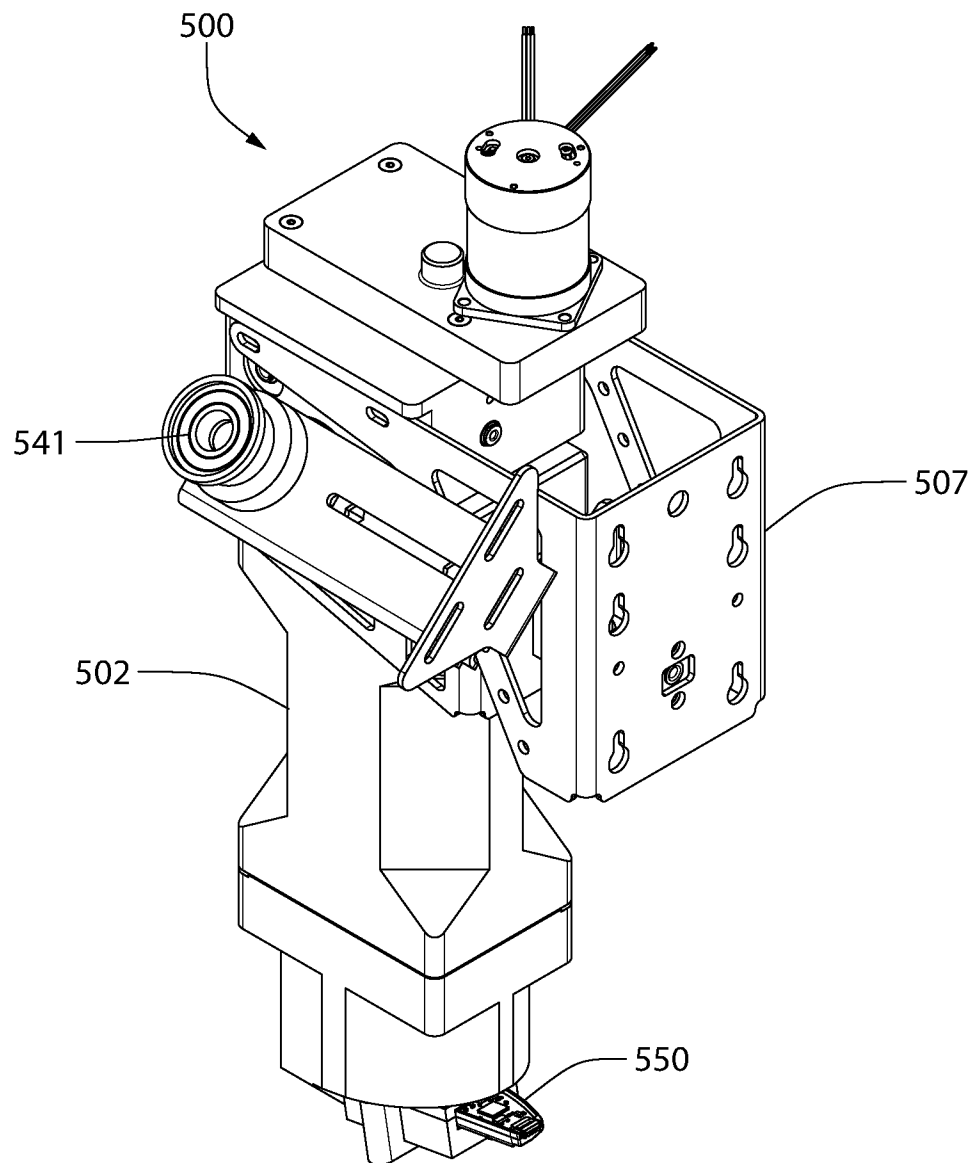


FIG. 11

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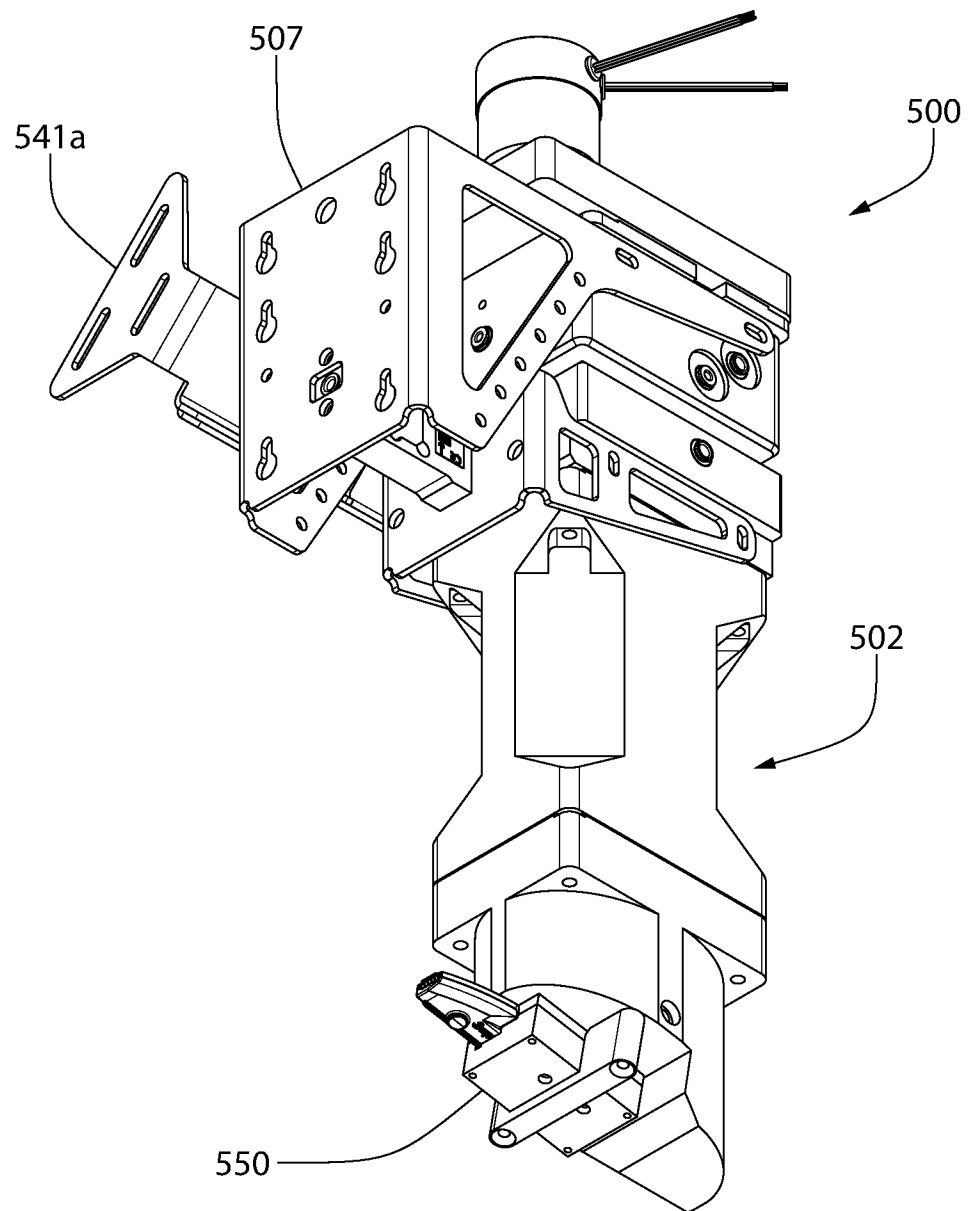


FIG. 12

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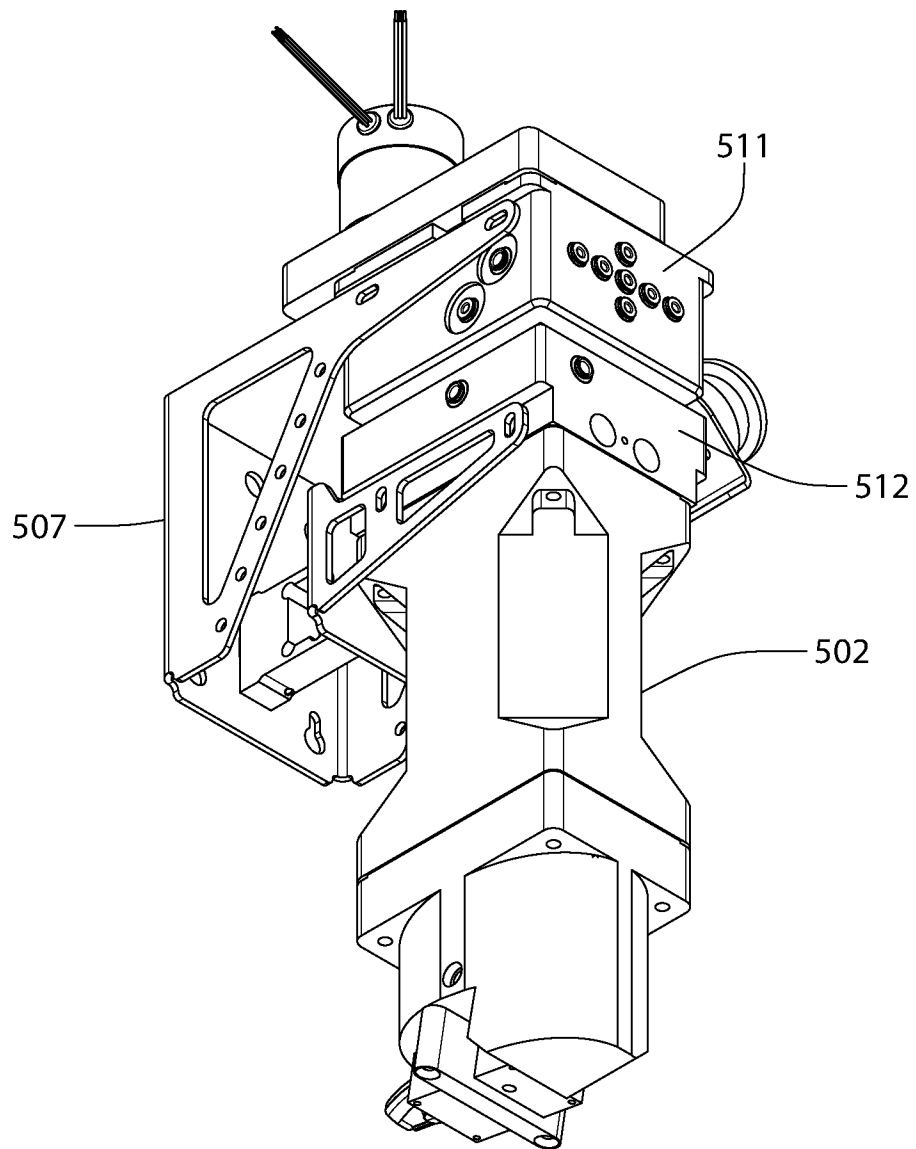


FIG. 13

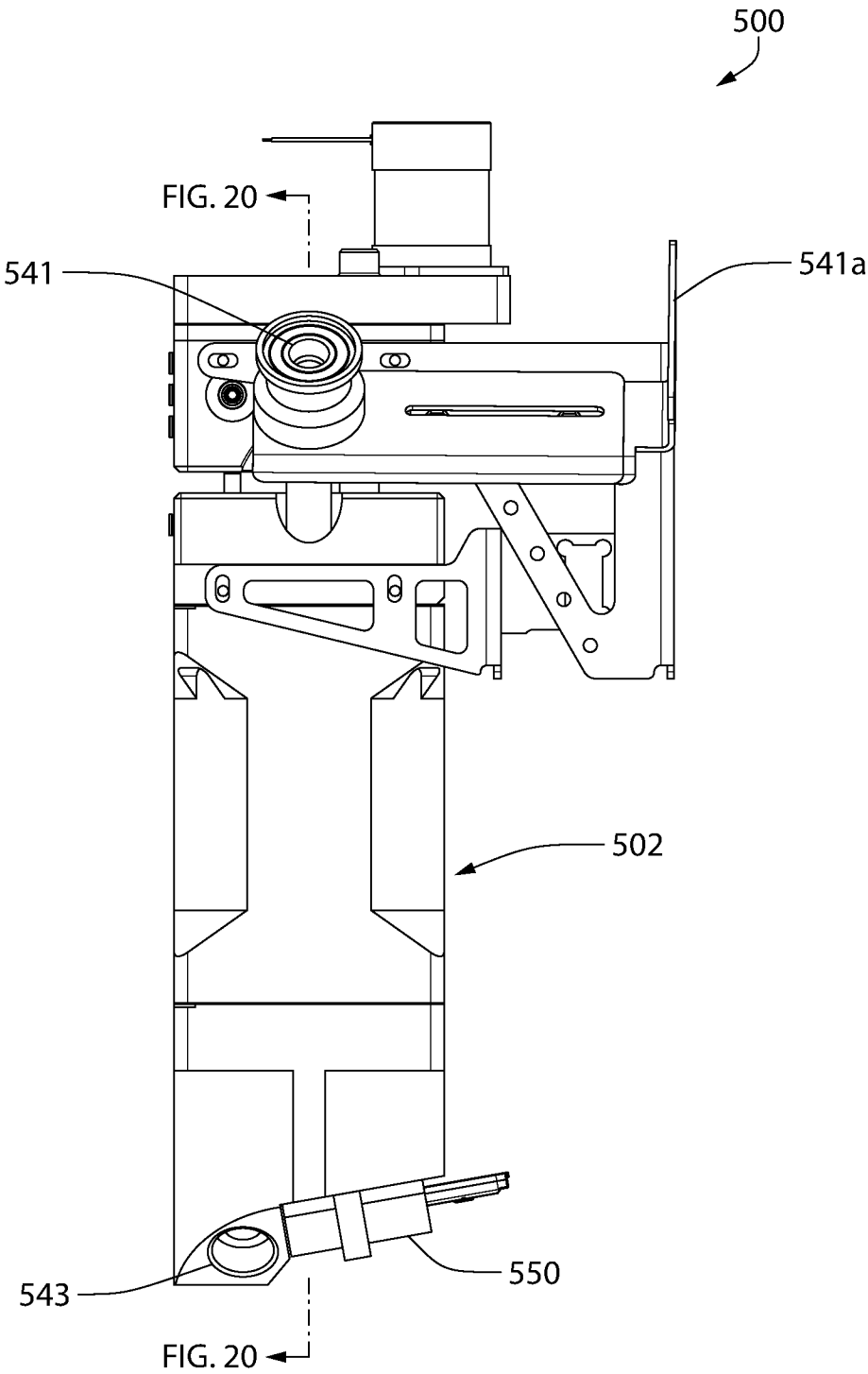


FIG. 14

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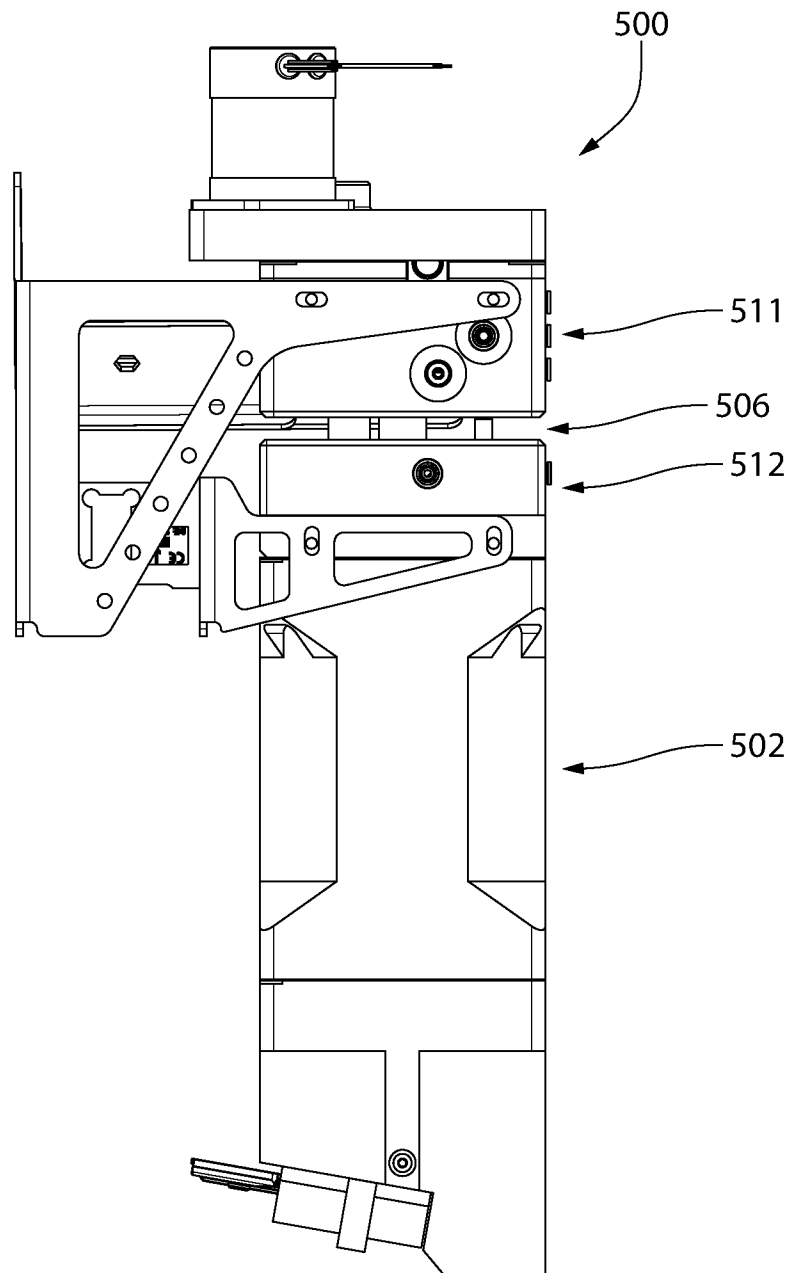


FIG. 15

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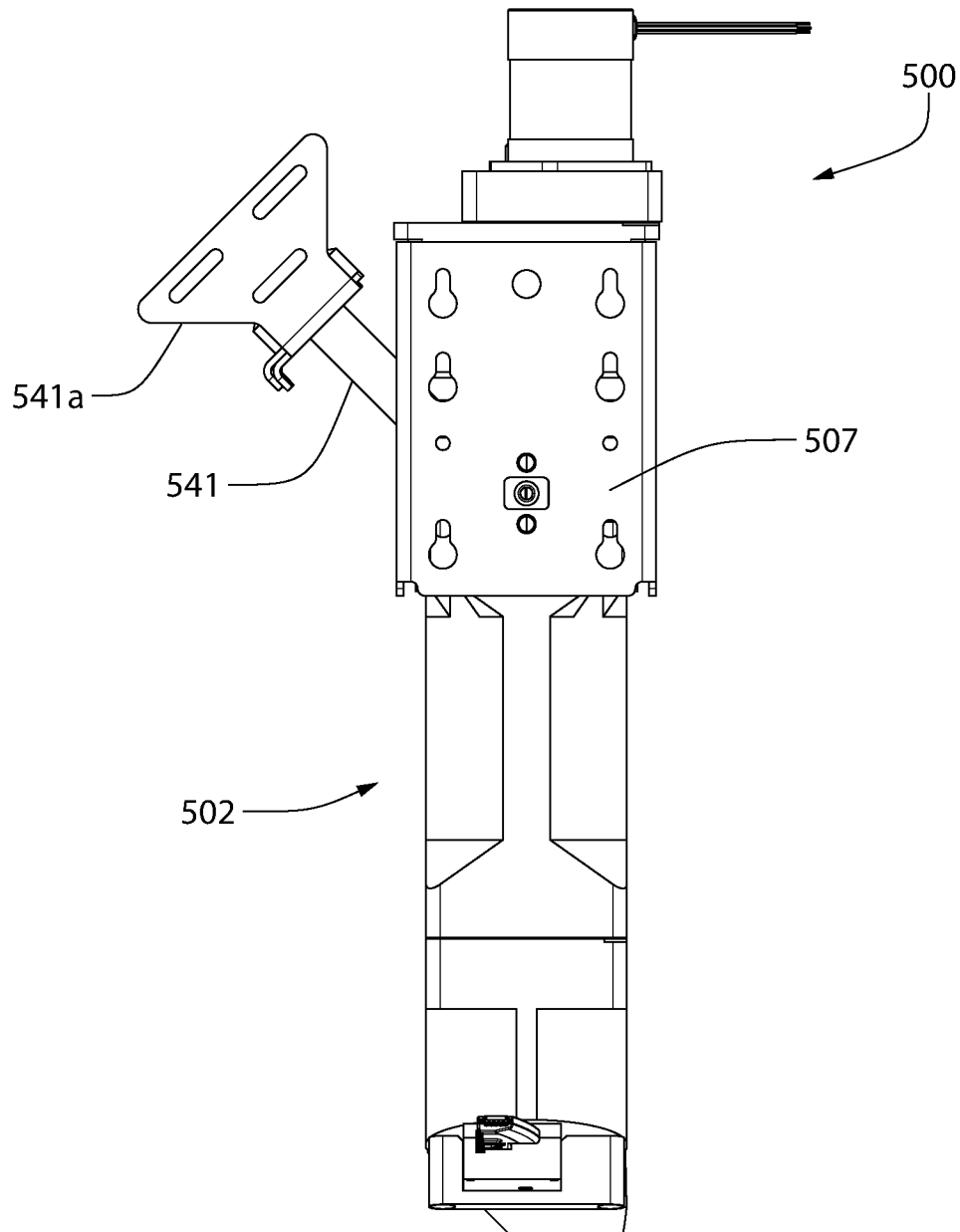


FIG. 16

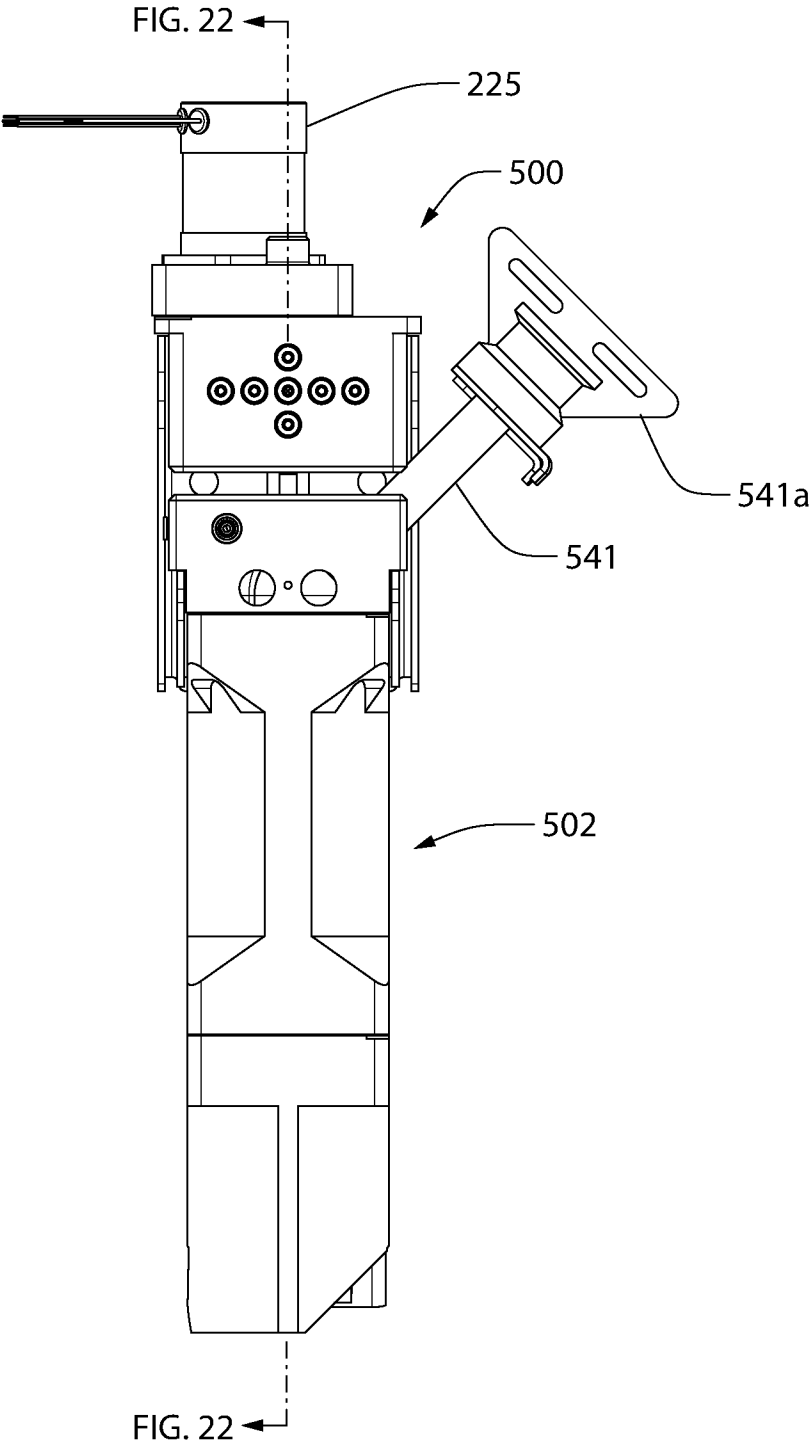


FIG. 17

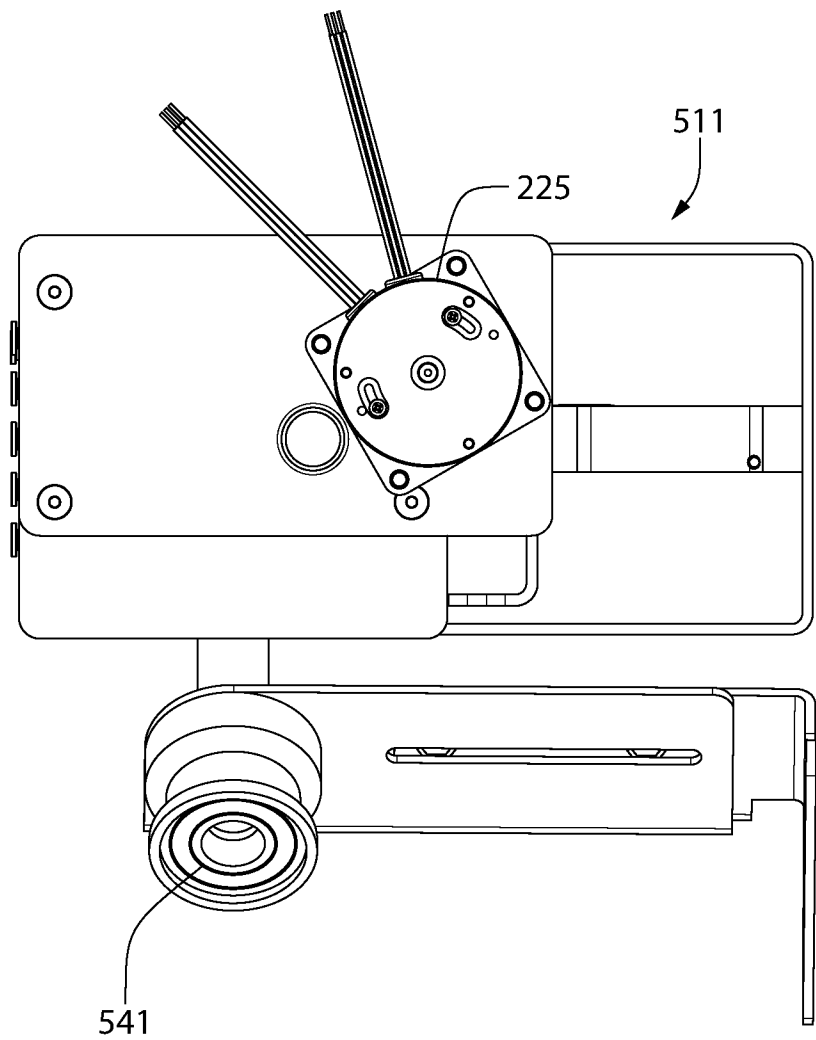


FIG. 18

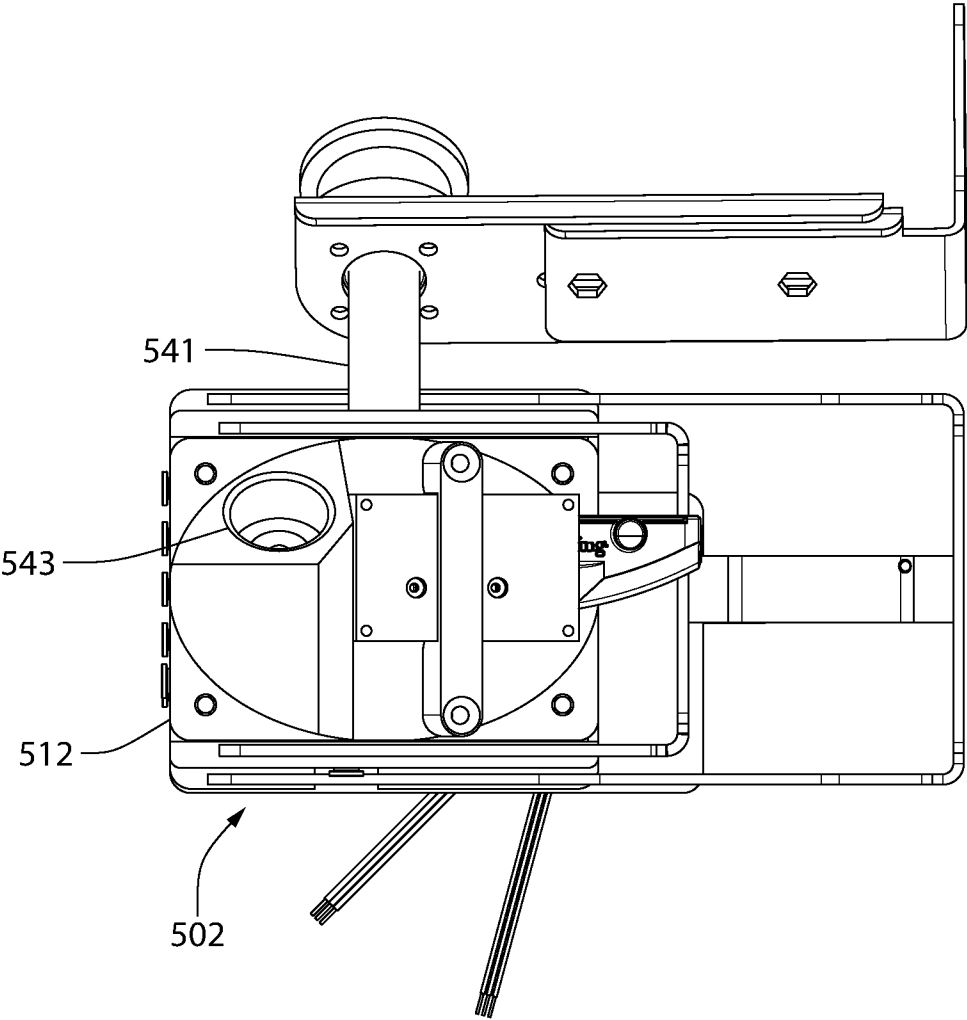


FIG. 19

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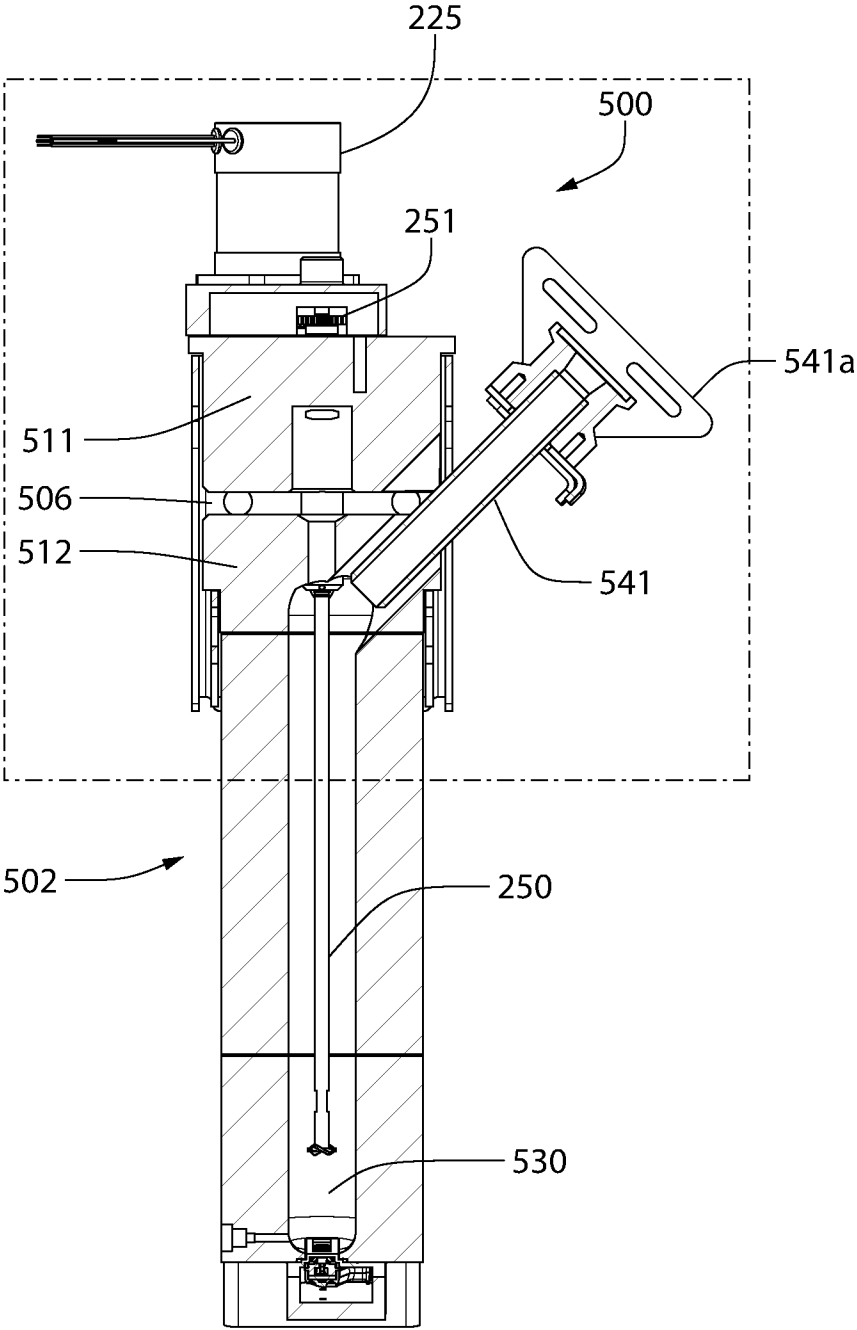


FIG. 20

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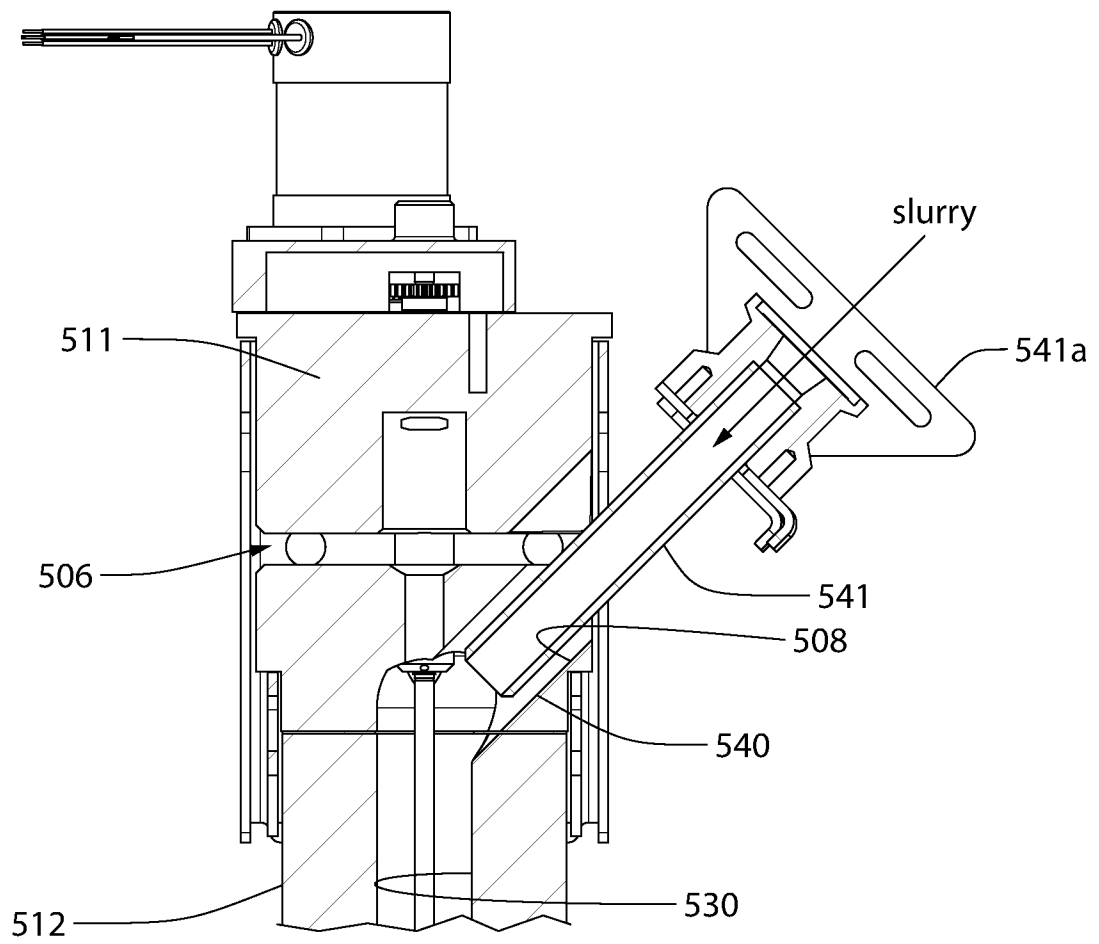


FIG. 21

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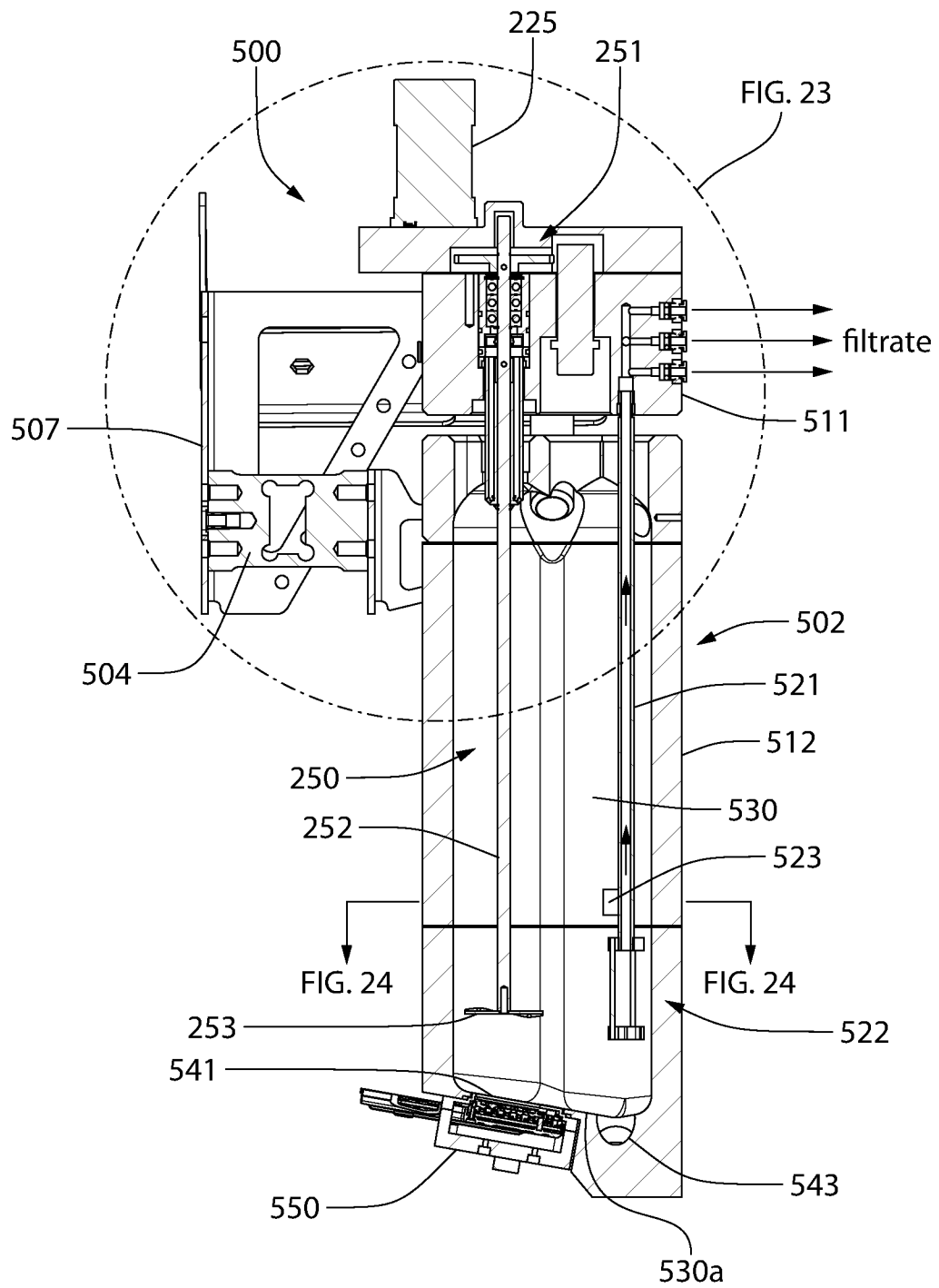


FIG. 22

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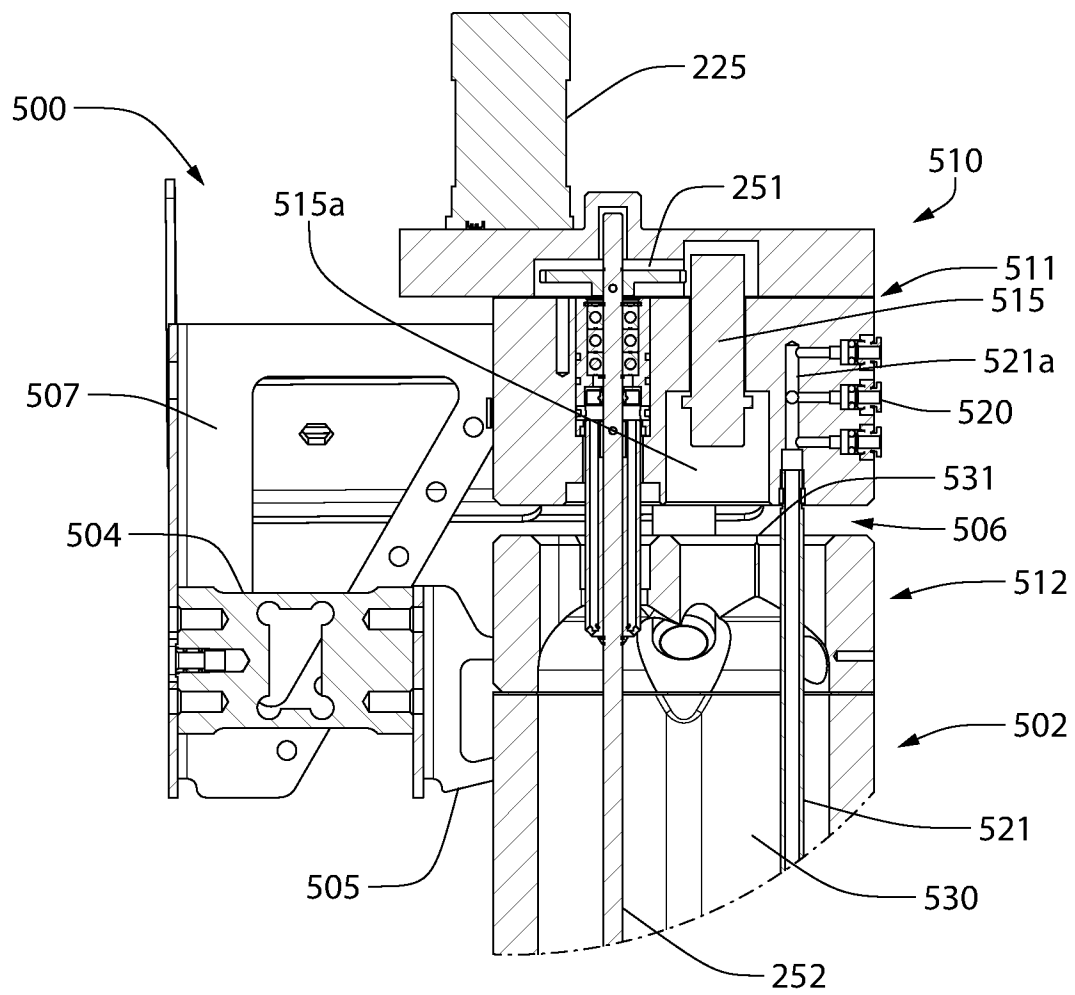


FIG. 23

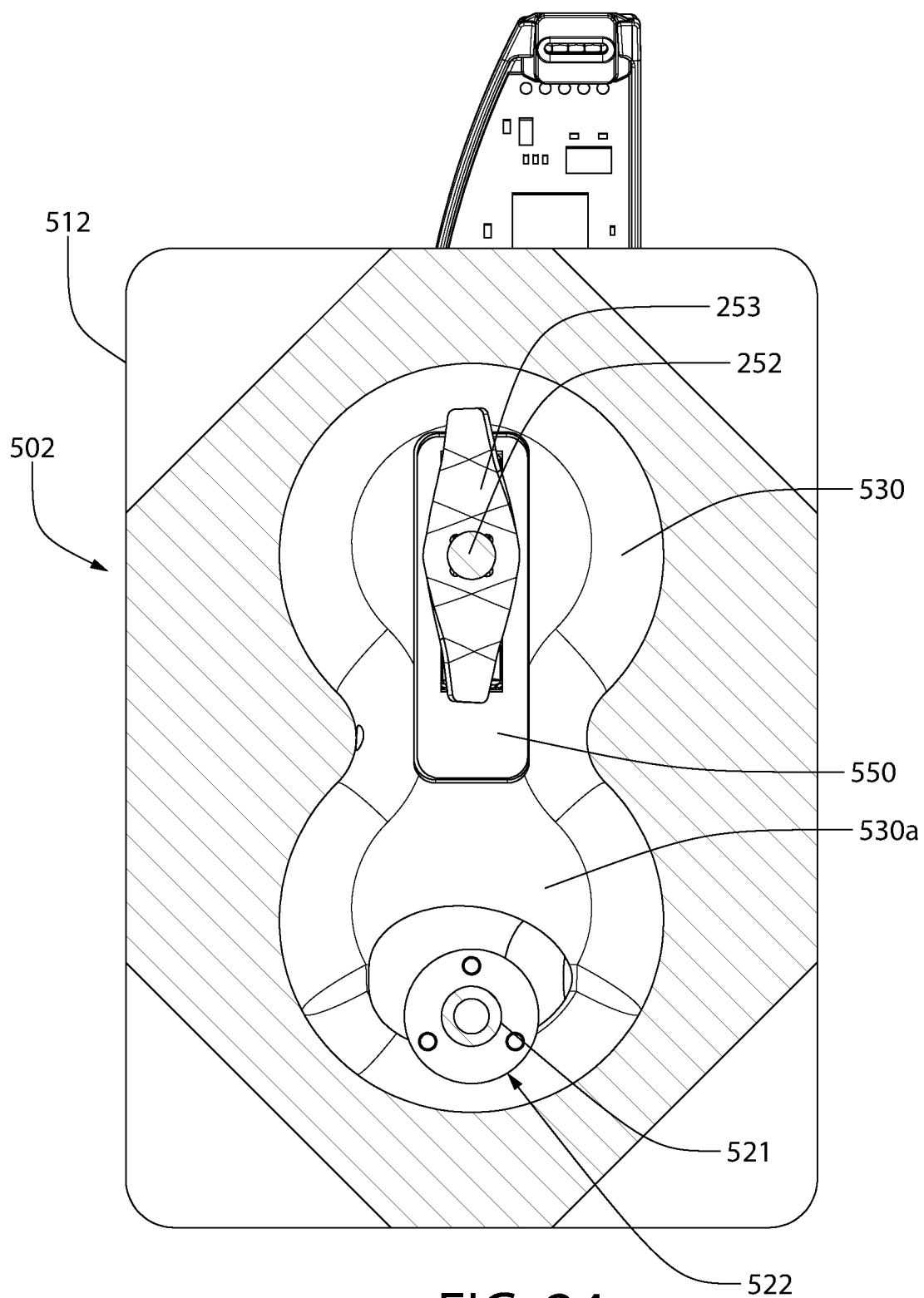


FIG. 24

## INTERNATIONAL SEARCH REPORT

International application No  
**PCT/IB2024/051820**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                     |                                                                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br><b>INV. G01N1/28 B01F25/50 G01N1/38 B01F35/00</b><br><b>ADD.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                     |                                                                         |
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                     |                                                                         |
| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br><b>G01N B01F</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                     |                                                                         |
| 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)<br><b>EPO-Internal, WPI Data</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                     |                                                                         |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                     |                                                                         |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Citation of document, with indication, where appropriate, of the relevant passages                                  | Relevant to claim No.                                                   |
| <b>X</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>US 2021/269331 A1 (ANDERSON GREGORY [US] ET AL) 2 September 2021 (2021-09-02)</b>                                | <b>1-5, 10-25, 30-32</b>                                                |
| <b>A</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>paragraph [0056] - paragraph [0067]; figures 3-5</b><br>-----                                                    | <b>6-9, 26-29</b>                                                       |
| <b>A</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>WO 2020/012369 A2 (PREC PLANTING LLC [US]) 16 January 2020 (2020-01-16) paragraph [0648] figure 283</b><br>----- | <b>1-32</b>                                                             |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                     |                                                                         |
| <p>* Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"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</p> <p>"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</p> <p>"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</p> <p>"&amp;" document member of the same patent family</p> |                                                                                                                     |                                                                         |
| Date of the actual completion of the international search<br><b>6 May 2024</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                     | Date of mailing of the international search report<br><b>16/05/2024</b> |
| Name and mailing address of the ISA/<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                     | Authorized officer<br><b>Liefrink, Feike</b>                            |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2024/051820

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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