



- (51) **International Patent Classification:**
B07B 1/28 (2006.01) *C02F 1/34* (2006.01)
B07B 1/46 (2006.01)
- (21) **International Application Number:**
PCT/US2015/038170
- (22) **International Filing Date:**
26 June 2015 (26.06.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
14/317,903 27 June 2014 (27.06.2014) US
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(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** BEACH DETECTION SENSORS FOR VIBRATORY SEPARATOR

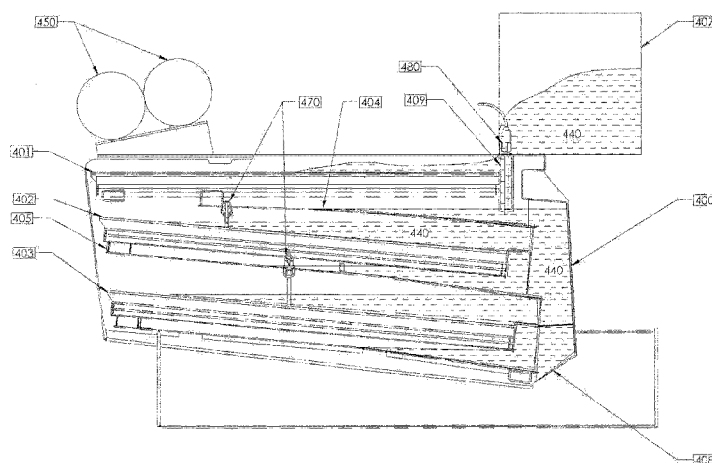


FIG. 14

(57) **Abstract:** An apparatus includes a screen capable of separating solids from a slurry having a liquid portion and a solid portion, and a first probe disposed beneath the screen to determine a position of a beach between a feed end and a discharge end of the screen, the beach being a transition where a substantial majority of the liquid portion of the slurry terminates. A method includes providing a slurry to a vibratory separator, measuring a property of a portion of the slurry adjacent to a reference probe, measuring a property of a composition adjacent to a first probe within the vibratory separator, and comparing measurements from the reference probe and the first probe to determine a position of the slurry.



BEACH DETECTION SENSORS FOR VIBRATORY SEPARATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims priority to U.S. Application No. 14/317,903, filed on June 27, 2014, in the United States.

BACKGROUND

[0002] Separators may be used in various industries such as the food industry, cleaning industry, waste water treatment, and others. The vibratory separator may include a generally horizontal table or an angled table with a perforated filter screen bottom. Fluid is deposited at the feed end of the vibratory separator. As the fluid travels along the length of the vibrating table, the fluid falls through the perforations in a separation screen to a reservoir below, leaving the solid particulate material behind. The vibrating action of the vibratory separator table conveys solid particles left behind to a discharge end of the separator table. The above described apparatus is illustrative of one type of vibratory separator known to those of ordinary skill in the art. In alternate vibratory separators, the feed end of the separator may be relatively closer to the ground than the discharge end. In such vibratory separators, the angle of inclination may require the movement of particulates in a generally upward direction. In still other vibratory separators, the table may not be angled, thus the vibrating action of the separator alone may enable particle/fluid separation. Regardless, table inclination and/or design variations of existing vibratory separators should not be considered a limitation of the present disclosure.

[0003] In the oilfield industry, drilling fluid, often called "mud," serves multiple purposes in the industry. Among its many functions, the drilling mud acts as a lubricant to cool rotary drill bits and facilitate faster cutting rates. Typically, the mud is mixed at the surface and pumped downhole at high pressure to the drill bit through a bore of the drill string. Once the mud reaches the drill bit, it exits through various nozzles and ports where it lubricates and cools the drill bit. After exiting through the

nozzles, the "spent" fluid returns to the surface through an annulus formed between the drill string and the drilled wellbore.

[0004] In addition to cooling the bit, the drilling mud carries the cuttings away from the drill bit at the bottom of the borehole to the surface. As a drill bit pulverizes or scrapes the rock formation at the bottom of the borehole, small pieces of solid material are left behind. The drilling fluid exiting the nozzles at the bit acts to stir-up and carry the solid particles of rock and formation to the surface within the annulus between the drill string and the borehole. Therefore, the fluid exiting the borehole from the annulus is a slurry of formation cuttings in drilling mud. Before the mud can be recycled and re-pumped down through nozzles of the drill bit, the cutting particulates are removed by a separator, such as a vibratory separator.

BRIEF DESCRIPTION OF DRAWINGS

[0005] FIG. 1 shows a perspective view of a separator in accordance with embodiments of the present disclosure.

[0006] FIG. 2 shows a side view of a separator in accordance with embodiments of the present disclosure.

[0007] FIG. 3 shows a side view of a separator in accordance with embodiments of the present disclosure.

[0008] FIG. 4 shows a top view of a separator in accordance with embodiments of the present disclosure.

[0009] FIG. 5 shows a top view of a separator in accordance with embodiments of the present disclosure.

[0010] FIG. 6 shows a front view of FIG. 5.

[0011] FIG. 7 shows a top view of a separator deck in accordance with embodiments of the present disclosure.

[0012] FIG. 8 shows a perspective view of FIG. 7.

[0013] FIG. 9 shows a top view of a separator deck in accordance with embodiments of the present disclosure.

- [0014] FIG. 10 shows a cross-sectional view of FIG. 9.
- [0015] FIG. 11 shows a top view of a separator deck in accordance with embodiments of the present disclosure.
- [0016] FIGS. 12 and 13 show cross-sectional views of a flow-back pan in accordance with embodiments of the present disclosure.
- [0017] FIG. 14 shows a diagram of a vibratory separator according to embodiments of the present disclosure.
- [0018] FIG. 15 shows a diagram of a vibratory separator in accordance with embodiments of the present disclosure.
- [0019] FIG. 16 shows a diagram of a vibratory separator in accordance with embodiments of the present disclosure.
- [0020] FIG. 17 shows a diagram of a vibratory separator in accordance with embodiments of the present disclosure.
- [0021] FIG. 18 shows a diagram of a vibratory separator in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

- [0022] Embodiments disclosed herein generally relate to an apparatus and methods for determining a position of a slurry during separation of solids from the slurry. For example, embodiments of the present disclosure relate to apparatuses and methods for determining a slurry depth and a position of a slurry beach. Some embodiments provide a separator having at least one probe disposed therein to monitor the movement of a slurry, such as the position of the beach and/or the depth of the slurry. As used herein, a slurry may comprise wellbore fluid, such as water, drilling fluid, oil, solids, such as drill cuttings, and/or other gases or slurries. The slurry may be comprised of an entirely slurry composition or a partial slurry/solid composition.
- [0023] Monitoring the movement of the slurry across a separator deck and/or screen, may be performed to maximize fluid capacity of the separator and longevity of the separator deck while ensuring a minimum separation of fluid from drill cuttings. As used herein, the term “separator deck” refers to at least one screen disposed in a

separator. According to some embodiments, a separator deck may include multiple screens. Each screen may be coupled to the separator by any means known in the art, for example, wedges, clamping systems, etc. Each separator deck as used herein may occupy a level of the separator. For example, the separator 100 shown in FIG. 1 includes three separator decks or levels: a top separator deck 110, a middle separator deck 120, and a bottom separator deck 130. One skilled in the art will understand that the number of separator decks disposed in a separator 100 is not intended to limit the scope of the present disclosure.

[0024] During separatory operations, the slurry may be deposited onto a feed end of a vibratory separator. The slurry may form a “pool” on the feed end of the vibratory separator. As the slurry progresses across the separator deck, at least a portion of the liquid and/or solids below a predetermined aperture size in the screen may drain through a screen disposed in the separator deck leaving the slurry now comprised substantially of solid matter (albeit, in some embodiments, with at least a portion of the liquid) to be discarded at a discharge end. The “beach” as used herein refers to a transition where a substantial majority of the liquid portion of the slurry terminates. For example, a beach may be a region or location where the pool of the slurry transitions to a region consisting of substantially solid matter and/or where the pool of the slurry terminates. When a beach includes a transition from a slurry region (having a composition with liquid and solid portions) to a solid portion region having a composition with a substantial majority of the solid portion of the slurry, the solid portion region may have some fluid remaining on the separated solids (e.g., a solid-liquid composition having less than 10 percent by volume, less than 5 percent by volume or less than 2 percent by volume). As used herein, the term “beach” may refer to a region and not a definite boundary line.

[0025] Embodiments disclosed herein relate to an apparatus and methods for monitoring the movement of a slurry, including determining a position of a beach and determining a depth of the slurry. For example, some embodiments disclosed herein include disposing a probe below a screen or separator deck of a vibratory separator for determining the location of the beach. The probe may be used to determine if fluid passes through the separator deck in a region proximate the probe. That is, the probe may monitor a region proximate the probe to determine if slurry is present.

[0026] One or more probes may be used to determine changes in the amount of fluid of the slurry, if any, that passes through the separator deck. For example, in embodiments determining a depth of the slurry, one or more probes may be disposed in desired regions of a vibratory separator for measuring the depth of the slurry, and a reference probe may be disposed either upstream, downstream or within the vibratory separator in a location where the slurry may completely surround the reference probe, such as a fluid collection cavity. Based on the data collected from the probes, a depth of the slurry around the one or more probes may be determined. The conditions of the vibratory separator (e.g., flow rate, angle of one or more separator decks, vibration speed, etc.) may be adjusted based on the determination of the depth of the slurry to increase, decrease or maintain the depth of the slurry. In embodiments determining a beach location, one or more probes may be disposed proximate a desired beach location, and/or one or more probes may be disposed at a position where the beach is not desired (e.g., a distance away from the desired beach location). For example, a first probe may be disposed at a location closer to a feed end than the desired beach. A second probe may be disposed at a location closer to the discharge end than the desired beach. A third probe may be disposed at the location of a desired beach. Based on the data collected from the probes, a location of the beach along the screen may be determined. The vibratory separator may be adjusted based on the determination of the location of the beach to affect the position of the beach. One skilled in the art will understand that the number and position of the probes is not intended to limit the scope of the present disclosure.

[0027] FIGS. 1-3 show a separator 100 in accordance with embodiments of the present disclosure. FIG. 1 shows the separator 100 without screens disposed therein. The separator 100 includes a separator deck 110 and a probe 140 disposed beneath the separator deck 110 for measuring at least one characteristic of a local volume around the probe 140, *i.e.*, a region proximate the probe 140 to determine the presence of the slurry in the local volume. Additionally, one skilled in the art will understand that embodiments disclosed herein may be used with a variety of fluid/solid separation devices, for example, separators for food processing, separators for waste water treatment, etc. Further, while embodiments described herein may be in reference to

applications in the oil and gas industry, the apparatus and methods described herein are limited to the oil and gas industry.

[0028] The probe 140 may determine a property of a volume or composition adjacent to the probe 140 (which may be referred to herein as a “local volume”). For example, as will be described in more detail below, the probe 140 may be used to determine a capacitance, heat capacity, viscosity, temperature, pressure, or other property of a composition (*e.g.*, slurry, air, drilling fluid, and/or other gases or liquids) present in a local volume adjacent to the probe 140. For example, when the position of a slurry covers a probe, the probe may determine the capacitance of the slurry, when the slurry is filtered through a screen over the probe, the probe may determine the capacitance of a liquid portion of the slurry, or when the position of the slurry does not cover or filter over the probe, the probe may determine the capacitance of the atmosphere in the local volume adjacent to the probe. The probe 140 may determine a property of the composition adjacent to the probe 140 by measuring a value of the property (*e.g.*, capacitance value, heat capacity value, etc.) or the probe 140 may simply detect a change in the property (*e.g.*, an increase or decrease in capacitance).

[0029] The property may be used to determine what fluids of the slurry are present within the local volume. For example, based on the property determined by probe 140, it may be determined that the composition adjacent to the probe includes gas (*e.g.*, atmosphere), slurry, one or more components of the slurry (*e.g.*, a liquid portion of a slurry), or combinations thereof. Based on the determined property, a specific composition (*e.g.*, type of fluid of the slurry) may be determined. The size of the local volume of the composition adjacent to the probe may vary based on the probe 140 used and the location and orientation of the probe 140 within the separator. For example, the local volume may encompass a volume approximately 1 inch from the probe 140 along the length of the probe. For a cylindrical probe having a radius of approximately 0.10 inches, the local volume may have a radius of 1.10 inches, which extends the length of the probe. The example of the local volume above is provided for illustrative purposes and is not intended to be limiting. In some embodiments, the local volume may be more or less than 1 inch from the probe 140 and extend along the length of the probe.

[0030] The length along a probe which a slurry covers may also vary. For example, a slurry (e.g., a solid-liquid mixture or a liquid) may be approximately equal to the length of the probe 140, or a length shorter or longer than the probe 140. A slurry may also cover a distance approximately equal to a width or length of the separator deck 110, or may cover a distance less than or greater than the width or length of the separator deck 110.

[0031] The probe 140 may be positioned in or on the separator 100 to identify a presence (or lack thereof) of a slurry in the local volume adjacent to the probe 140. For example, the probe 140 may be disposed near a desired location of a beach for monitoring the location of the beach. In some embodiments, the probe 140 may be positioned under the separator deck 110 such that slurry passing through the separator deck may enter the local volume adjacent to the probe 140. Accordingly, as slurry enters the region adjacent the probe 140, *i.e.*, the local volume, the probe 140 measures or detects at least one property of the filtered slurry entering or deposited in the local volume adjacent to the probe 140. Based on the presence of slurry in the local volume adjacent to the probe 140 or contact or lack of contact of the slurry with the probe 140, a position or location of the slurry with respect to the separator deck 110 can be determined.

[0032] Referring to FIG. 2, probe 140 is provided beneath a separator deck 120 (*i.e.*, beneath a screen of the separator deck) to determine a property of the local volume. Based on the property of the local volume, a user or operator may determine if slurry is present in the local volume. The probe 140 may be disposed between the separator deck 120 and a flow-back pan 123 in a location proximate a desired or estimated beach location. For example, the probe 140 may be disposed beneath a desired beach location on the separator deck 120. According to some embodiments, the probe 140 may be disposed beneath a location where the beach is not desired. For example, the probe 140 may be disposed beneath the separator deck a short distance before and/or after the desired beach location. The desired beach location may be chosen or estimated based on the slurry to be filtered. For example, in drilling applications, the desired beach location may be chosen based on the type of formation being drilled, the type of mud used, the flow rate of the fluid entering the separator, acceptable

particle size, fluid viscosity, fluid gel point, need to recover loss control material (LCM), and/or need to reject low gravity (fine particle) solids.

[0033] According to some embodiments a desired beach location may be about 75% of the length of a separator deck from a feed end of the separator. According to some other embodiments the desired beach location may be about 50%-95% of the length of a separator deck from the feed end. Although, reference to a distance from a feed end is provided, one having ordinary skill in the art will understand that a desired location of the beach may be determined from the discharge end, for example, a desired beach location may be about 25% of the length of a separator deck from a discharge end.

[0034] The probe 140 may be any probe known in the art to measure a property of a composition adjacent to the probe. As the amount of slurry entering the local volume and/or being deposited on the probe 140 changes, so will the property of the local volume adjacent to the probe 140. According to some embodiments, the probe 140 may be a capacitance probe that measures the capacitance of a local volume adjacent to the probe 140. For example, a capacitance probe (*e.g.* Liquicap FMI151 from Endress + Hauser, Reinach, Switzerland; or Model 167 from Robertshaw Industrial Products, Maryville, Tennessee) may be used to measure capacitance of a composition adjacent to the probe. The measured capacitance may correspond to an amount of slurry adjacent to the probe, *i.e.* a higher capacitance may correspond to more slurry being deposited on the probe 140, while a lower capacitance may correspond to less slurry entering the local volume adjacent to the probe 140 and/or being deposited on probe 140. A thermal diffusivity probe (*e.g.* FLT93 from Fluid Components International LLC, San Marcos, California) may also be used to monitor the composition adjacent to the probe. The thermal diffusivity probe may work by monitoring a change in temperature as well as the power/heat input of the probe 140 over a period of time to determine the thermal conductivity of the composition within the local volume adjacent to the probe.

[0035] According to some embodiments, an outer surface of the probe 140 may be coated with a non-stick compound such as polytetrafluoroethylene (*e.g.* TEFLON, by DUPONT, Delaware), to prevent the filtered slurry from damaging or caking on a

surface of the probe 140. As slurry enters the local volume and is deposited on the probe 140, a slurry layer or cake on the probe 140 may affect the accuracy of the probe 140 measurements, as the probe 140 measurements may reflect properties of the slurry layer, not the current properties of the composition within the local volume adjacent to the probe. Thus, the polytetrafluoroethylene coating may allow slurry to be repelled from the surface of the probe 140 and enhance the accuracy of the probe 140 measurements.

[0036] The probe 140 may be generally cylindrical in shape having a diameter that is less than the length of the probe 140. According to some embodiments the diameter of the probe may not be constant from a first end of the probe to a second end of the probe. According to some embodiments, a diameter of the probe may be about 0.6 inches. According to some embodiments, a diameter of the probe may be less than 1 inch. According to some embodiments, a diameter of the probe may be greater than one inch. As seen in FIG. 13, a central axis 141 of the probe may be defined as a longitudinal line that runs through the center of the probe 140. According to some embodiments, the central axis of the probe 140 is about parallel to a plane of the separator deck 110.

[0037] The probe 140 may be operatively coupled to an electronic control module (ECM) or database (not shown), which is configured to receive a signal from the probe 140 and display the signal to a user or operator. The signal will indicate to the user or operator a property of the local volume measured by the probe 140. Based on the signal, the user or operator may determine if slurry is present in the local volume adjacent to the probe. Based on the location of the probe 140 and the presence of slurry in the local volume, the location of a beach on separator deck 120 may be determined.

[0038] For example, referring briefly to FIG. 4, a top view of the first separator deck 110 of a separator in accordance with embodiments of the present disclosure is shown. The left side of FIG. 4 shows the separator deck 110, while the right side shows a cutaway view exposing the configuration of the probe 140 disposed below the separator deck 110. A screen (not shown) may be disposed across the separator deck 110. As shown in FIG. 4, probe 140 is disposed substantially perpendicular to a

direction of slurry flow, indicated by arrow 4, along separator deck 110. Probe 140 is located about 75% of the length of the separator deck 110 from a feed end 114 of the separator deck 110. According to other embodiments the probe 140 may be located between approximately 50% and 95% of the length of the separator deck 110 from a feed end of the separator deck 110. According to some embodiments, two or more probes may be disposed beneath a separator deck 110.

[0039] For illustrative purposes, say the desired beach location is about 75% of the separator deck 110 from a feed end 114. Thus, the probe 140 as pictured in FIG. 4 is disposed at a desired beach location. As drilling fluid is provided to the vibratory separator 100 and the drilling fluid flows along separator deck 110, probe 140 may monitor a region or local volume proximate the probe 140 to determine the presence of slurry (*i.e.* drilling fluid). The probe may send a signal to an ECM or database. If the probe 140 detects slurry is present in the local volume adjacent to the probe 140, then a user or operator may determine that the beach is located between the desired beach location and the feed end 114. If the probe 140 determines slurry is not present in the local volume, then a user or operator may determine that the beach is located between the feed end 114 and the desired beach location. Based on the signal, the ECM or user may adjust operating conditions of the vibratory separator 100 to change the location of the beach. That is, if the beach is located between the desired beach location and the discharge end, the flow rate may be decreased, the angle of the separator deck 110 increased, the vibratory force and/or speed may be increased, the motion profile changed, and/or the mesh size of the screen changed in order to shorten the length of the pool. If the beach is located between the feed end 114 and the desired beach location, then the flow rate may be increased, the angle of the separator deck 110 decreased, the vibratory force may be decreased, the motion profile changed, and/or the mesh size of the screen changed to move the beach closer to the desired beach location.

[0040] According to some embodiments, more than one probe 140 may be used to determine the location of the beach. For example, a first probe 140 may be disposed before a desired beach location (*i.e.* between the feed end 114 and the desired beach location), while a second probe 140 may be disposed after a desired beach location (*i.e.* between the desired beach location and a discharge end). Thus, the first and

second probe may define a desired beach region. The first and second probe may send corresponding first and second signals to an ECM or database. Based on the signals, the ECM or user may determine a location of the beach and adjust the vibratory separator to change the location of the beach, as needed.

[0041] For example, if the first and second signals are different, then the beach is located in the desired beach region. As the beach is in the desired beach region, the user or operator may determine not to adjust the vibratory separator. If the first and second signals are the same, and slurry is not detected, then the beach may be located between the feed end 114 and the desired beach region and the user or operator may adjust operating conditions of the vibratory separator 100 to lengthen the pool (*i.e.* increase the flow rate, decrease the angle of the separator deck 110, decrease the vibratory force may be, change the motion profile, and/or change the mesh size of the screen). If the first and second signals are the same, and slurry is detected, the beach may be located between the desired beach region and the discharge end. Accordingly, the user or operator may adjust operating conditions of the vibratory separator 100 to shorten the pool (*i.e.* decrease the flow rate, increase the angle of the separator deck 110, increase the vibratory force may be, change the motion profile, and/or change the mesh size of the screen).

[0042] Additional examples of probe 140 configurations are discussed below. One skilled in the art will understand that the number of probes 140 and their position with respect to the separator deck 110 is not intended to limit the scope of the disclosure.

[0043] In a vibratory separator with multiple separator decks, at least one probe 140 may be disposed below one or more of the separator decks. For example, at least one probe 140 may be disposed beneath the first separator deck 110, at least one probe 140 may be disposed beneath the second separator deck 120, and at least one probe 140 may be disposed beneath the third separator deck 130. According to some embodiments, a plurality of probes may be disposed beneath the first and second separator decks 110, 120. As seen in FIG. 3, three probes 140 are disposed beneath each separator deck 110, 120, 130. The number of probes 140 disposed beneath each separator deck is not intended to be a limitation on the scope of the present disclosure. One having ordinary skill in the art will understand that any number of probes 140

may be disposed beneath each separator deck or a selected number of separator decks without departing from the scope of the present disclosure. For example, according to some embodiments, one probe 140, two probes 140, or more than three probes 140 may be disposed beneath one or more of the multiple separator decks.

[0044] According to some embodiments, the probe 140 may be disposed between the separator deck 110 and a flow-back pan 113. As seen in FIG. 3, flow-back pan 113 may be disposed beneath separator deck 110 to collect the filtered slurry that passes through the screen of the separator deck 110. Referring now to FIGS. 6, 8, and 10, the flow-back pans 113, 123, and 133 may include a middle partition 118 to divide the flow of the filtered slurry into a left side and a right side. The partition 118 may be, for example, a vertically oriented plate or divider. The partition 118 may extend along a full length of flow-back pans 113, 123, and 133 or along a portion of flow-back pans 113, 123, and 133 and may be welded or secured in place with mechanical fasteners, for example, screws, rivets, or other fasteners known in the art. The middle partition 118 may allow slurry to be more evenly distributed in each of the flow-back pans 113, 123, and 133.

[0045] A separator deck may have a flow-back pan disposed beneath, such that a first separator deck has a first flow-back pan disposed beneath, a second separator deck has a second flow-back pan disposed beneath, and a third separator deck has a third flow back pan disposed beneath. In embodiments having multiple separator decks not every separator deck may have a flow-back pan. As pictured in FIG. 3, the flow-back pans may be included to distribute slurry between separator decks. For example, flow-back pan 113 may be configured to direct a first filtered slurry from the first separator deck 110 to the second separator deck 120. According to some embodiments, second flow-back pan 123 may direct a second filtered slurry from the second separator deck 120 to a third separator deck 130. According to some embodiments, a third flow-back pan 133 may provide the filtered slurry from the third separator deck 130 to a storage vessel or secondary separation device (not shown). According to some embodiments, the third separator deck 130 does not include a flow-back pan. Instead, the filtered slurry may be directly transferred to a storage vessel or secondary separation device for further processing.

[0046] According to some embodiments, the probe 140 may be disposed between each separator deck and flow-back pan. For example, at least one probe 140 may be disposed between the first separator deck 110 and the first flow-back pan 113, at least a middle probe 140 may be disposed between the second separator deck 120 and the second flow-back pan 123, and at least a lower probe 140 may be disposed between the third separator deck 130 and the third flow-back pan 133. According to embodiments where the third separator deck 130 may not have a corresponding flow-back pan, a probe 140 may be disposed beneath the third separator deck 130 and not in a corresponding flow-back pan. According to some embodiments, a plurality of probes 140 may be disposed between each separator deck and flow-back pan, as shown in FIG. 3. One of ordinary skill in the art will appreciate that various configurations of separator decks, probes, and flow-back pans may be used in accordance with embodiments disclosed herein and the scope of the application is not limited to any one configuration.

[0047] Still referring to FIG. 3, a reference probe 119 may be included in the separator 100. According to some embodiments, the reference probe 119 may be the same make and model as the probe 140. The reference probe 119 may be disposed in a feed end of the separator deck 110 perpendicular to a direction of fluid flow. According to some embodiments, the reference probe 119 may be disposed parallel or at an angle to the direction of fluid flow. According to some embodiments, the reference probe 119 may be disposed in a chamber at a feed end of the separator 100. According to some other embodiments, the reference probe 119 may be disposed in a mud box at the feed end of the separator 100. As one of ordinary skill in the art will recognize, the mud box may be a structure positioned on the separator above the feed end configured to receive and distribute slurry to the separator. The reference probe 119 may be shorter in length than probe 140. According to some embodiments, the reference probe 119 may be disposed beneath a single separator deck of a plurality of separator decks, for example, beneath separator deck 110. According to other embodiments, the reference probe 119 may be disposed beneath each separator deck, for example, beneath separator decks 110, 120, and 130. According to other embodiments, the reference probe 119 may be disposed above at least one separator deck. The reference probe 119 may be operatively coupled to an ECM. The reference probe 119 may be

configured to send a reference signal to the ECM corresponding to a property of a local volume of the reference probe 119, wherein the reference probe 119 is coated in drilling fluid.

[0048] The reference signal from the reference probe 119 is indicative of a significant amount of slurry entering a local volume of probe 119 and being deposited on the reference probe 119. The reference probe 119 may be disposed at a feed end of the separator 100 where it may receive a stream of filtered slurry. A control signal or control value indicates when a probe 140 is exposed to air and/or no or minimal amounts of filtered slurry (in other words a minimal amount of slurry is entering the local volume of probe 140). A control value may be known for a given probe 140. For example, a control value may be about 0 pF for a probe 140 exposed to air. The reference signal and control value may be used to define bounds of exposure signal measured by the probe 140 at a given time, *i.e.* the probe 140 being coated in slurry and no slurry entering the local volume. As used herein, the term “reference signal” will refer to the signal from the reference probe 119 indicating a significant amount of slurry in the local volume adjacent to the reference probe 119 and coating the reference probe 119 and the term “control value” will refer to a signal or value from the probe 140 corresponding to no or a minimal of slurry entering the local volume of probe 140. Thus, depending on the signals from the reference probe and the probe 140 an amount of slurry deposited on probe 140 may be determined.

[0049] According to some embodiments a control value may be determined. For example, the control value may be determined by recording a signal produced by the probe 140 when exposed only to air or minimal amounts of slurry. One having ordinary skill in the art will readily understand that due to the vibratory nature of the separator, even when the probe 140 is located between the beach and the discharge end of the vibratory separator, some amount of filtered slurry may be deposited on the probe 140. Thus, a control value of a probe 140 exposed only to air may serve as an approximation for a signal from the probe during operation. One having ordinary skill in the art will readily understand that determining a location of the beach may be performed without a reference signal or a control value.

[0050] Different slurries (*e.g.*, muds) have different properties, *e.g.*, dielectric constant and heat capacity, and will produce different signals with probe 140 based on these properties. For example, a water based slurry may have a higher dielectric constant than an oil-based mud. Thus, a signal from probe 140 corresponding to minimal amounts of a water-based slurry in the local volume may be similar to a signal from probe 140 corresponding to a substantial amount of oil-based slurry in the local volume. Therefore, determining a signal for a probe, *i.e.*, a reference probe 119 fully coated in, for example, a drilling fluid, aids in accurately analyzing the signals from probe 140. Thus, the reference probe allows calibration of the incoming signal from probe 140 to be performed as the properties of the slurry, *i.e.* type of mud, changes during operation. A reference probe may be disposed in a fluid collection cavity coupled to a vibratory separator, where the fluid collection cavity may be a chamber or through-hole having a size and shape sufficient to collect enough slurry to completely surround the reference probe. For example, a fluid collection cavity may be a conduit leading into or out of the vibratory separator (where slurry may flow around the reference probe as it enters or exits the vibratory separator), a mud box, a chamber proximate one or more separator decks within a vibratory separator (where slurry may flow down the separator deck and collect into the chamber around a reference probe), or have a channel configuration, as described with reference to the channel 117 shown in FIGS. 12 and 13.

[0051] For example, a signal produced by the reference probe 119, may be used to determine other characteristics of slurry beyond the property *i.e.* capacitance or thermal conductivity, directly measured by the reference probe 119. If probes 119 and 140 are capacitance probes, the capacitance signal produced by the reference probe 119 may be used to determine if a slurry is oil-based or water-based. Determining the other characteristics of the slurry, *e.g.*, if a slurry is oil-based or water-based may aid the user or operator in interpreting the signal from probe 140, as a water-based mud may have a different capacitance than an oil-based mud.

[0052] The probe 140 and the reference probe 119 may be mounted to a frame of the separator 100, a basket of the separator 102, the separator deck 110, 120, 130 or the flow-back pan 113, 123. The probe 140 and the reference probe 119 may be removably mounted within the separator 100 such that they may be removed and

replaced if damage occurs during operation. The following description is provided with respect to probe 140, but one having ordinary skill in the art will understand that the reference probe 119 may be mounted in a similar manner. The probe 140 may be removably mounted within the separator 100 by any means known in the art. For example, a first end of the probe 140 may be threaded into a wall of the flow-back pan 113. A second end of the probe 140 may also be threaded into an opposite wall or middle partition 118 of the flow-back pan 113.

[0053] According to another embodiment, the second end of the probe 140 may be inserted into a receiving tube, cup or the like welded to the opposite wall of the flow-back pan 113, or middle partition 118. The cup may be lined with rubber to secure the second end of the probe 140 in place and dampen vibrations experience by probe 140. According to another embodiment, probe 140 may be mounted using Vanstone flanges at a first and second end of the probe 140 to secure the probe 140 to the flow-back pan 113. Although the above mounting methods have been described with respect to a flow-back pan 113, one having ordinary skill in the art will understand that a similar technique may be used to mount the probe 140 to a frame of the separator 100 and a basket 102 of the separator 100 without departing from the scope of the application.

[0054] According to another embodiment, a pair of brackets or flanges may be welded to a bottom of the separator deck 110 and a first end of the probe 140 may be attached to a first bracket and a second end of the probe 140 may be attached to a second bracket. The first and second ends of the probe 140 may be attached to the brackets using the above described attachment mechanisms, for example, threads, Vanstone flanges, and a thread and rubber-cup configuration.

[0055] Referring to FIGS. 5-11, additional configurations of the probe 140 are shown. Although the following embodiments are shown with respect to separator deck 110, one having ordinary skill in the art will readily understand that the configurations shown in FIGS. 4-11 may be used in any combination for the second or subsequent separator decks *e.g.* separator decks 120 and 130. Further, although the embodiments shown in FIGS. 8, 10, and 12 include a flow back pan 113, one having ordinary skill in the art will readily understand that similar configurations may be implemented

without a flow-back pan 113. For example, the probe 140 may be mounted to a wall of a basket 102, the separator deck 110, or the separator 100.

[0056] FIG. 5 shows a top view of the first separator deck 110 of a separator in accordance with embodiments of the present disclosure. The left side of FIG. 5 shows the separator deck 110, while the right side shows a cutaway view exposing the configuration of probes 140 disposed below the separator deck 110. A screen (not shown) may be disposed on the separator deck 110. The reference probe (not shown) may be disposed in a fluid collection cavity or chamber near a feed end 114 of the separator. Similar to FIG. 4, the probes 140 are disposed substantially perpendicular to a direction, indicated by arrow 4, of fluid flow along the separator deck 110. Two probes 140 are disposed proximate a desired beach location, such that a first probe 140 is disposed a distance from the feed end 114 less than a desired beach location and a second probe is disposed a distance from the feed end 114 greater than a desired beach location. For example, if a desired beach location is 75% of the length of the separator deck from a feed end 114, the first probe 140 may be disposed at a position corresponding to 70% of the length of the separator deck 110 from the feed end 114 and the second probe may be disposed at a position corresponding to 80% of the length of the separator deck 110 from a feed end. In other embodiments, the first probe 140 may be disposed at a position approximately 65% of the length of the separator deck 110 from the feed end 114 and the second probe may be disposed at a position corresponding to 85% of the length of the separator deck 110 from the feed end 114. One having ordinary skill in the art will understand that any number of probes 140 may be disposed proximate a desired beach location and at various distances from the desired beach location without departing from the scope of the present disclosure.

[0057] FIGS. 7 and 9 show top views of a separator deck of a separator according to embodiments of the present disclosure. In this instance separator deck 120 is illustrated, but the method may be applied to any deck of the shaker. Arrows 4 indicate a direction of flow along the separator deck 120. A reference probe (not shown) may be disposed near a feed end 114 of the separator. A probe 140 may be disposed substantially parallel to a direction of fluid flow. As seen in FIG. 7, the probe 140 may span an entire length or substantially the entire length of the separator

deck 120. A first end of the probe may be mounted to a wall of the flow-back pan, basket, or separator near a feed end; while a second end of the probe 140 may be mounted to a wall of the flow-back pan, basket, or separator near a discharge end.

[0058] As seen in FIG. 9, the probe 140 parallel to the direction of flow along the separator deck 120 may span a portion of the length of the separator deck 120 near a desired beach location; that is, the probe 140 is disposed such that it intersects a boundary corresponding to the desired beach location. According to this embodiment, a support wall 116 may be welded or mounted (*e.g.*, by mechanical fasteners, adhesives, etc.) to a flow back pan, a basket, the separator deck, or the separator, below a second separator deck 120 to receive a first end of the probe 140. Referring to FIG. 10, the support wall 116 may be configured such that it does not substantially interfere with the flow of filtered slurry. A second end of the probe 140 may be mounted to a wall of the flow-back pan, basket, the separator deck 120 or separator near a discharge end. According to some embodiments, more than two probes 140 may be disposed parallel to a direction of fluid flow without departing from the scope of the present disclosure.

[0059] FIG. 11 shows a top view of the separator deck 120 of a separator according to embodiments of the present disclosure. Arrow 4 indicates a direction of flow across separator deck 120. FIG. 11 shows probe 140. A reference probe (not shown) may be disposed at the feed end 114 of the separator 100. The probe 140 is disposed at an angle with respect to a direction of fluid flow along separator deck 120. For example, the probe 140 may be disposed at an angle of about 45° with respect to the direction of fluid flow across separator deck 120. According to some embodiments, the probe 140 may be disposed at an angle of about 30° to 60°. The probe 140 may be disposed proximate a desired beach location. The probe 140 may intersect a line about perpendicular to the direction of fluid flow along the deck corresponding to the desired beach location. For example, if a desired beach location is about 75% the length of the separator deck from a feed end 114, the probe 140 may intersect a line corresponding to a distance about 75% the length of the separator deck 120.

[0060] Referring to FIGS. 12 and 13, embodiments of the present disclosure may also include a gutter or channel 117 disposed proximate the probe 140 or the reference

probe to funnel or direct filtered slurry from a separator deck 120 to the probe 140. The channel 117 is provided in the separator to collect the filtered slurry as it passes through the screen (not shown) of separator deck 120 to provide a concentrated collection of the filtered slurry to a local volume adjacent to the probe 140 for measurement. The channel 117 may have a cross-section that is v-shaped, rectangular, trapezoidal, hemispherical, or any other channel shape known in the art for collecting slurry. The channel 117 may be provided with a series of apertures or holes in the sidewalls, bottom portion, or a combination of sidewalls and the bottom portion to allow slurry to collect in the channel 117 and exit the channel 117. The apertures may be sized such that any particulate matter that passes through the separator deck 120 will also pass through the channel 117 and not clog the apertures. The channel 117 may be welded to the walls of the flow-back pan 123. One having ordinary skill in the art will understand that the channel 117 may also be mechanically fastened to the walls of the flow back pan 123, with screws, rivets, and other mechanical fasteners known in the art. According to some embodiments, the channel 117 may be welded or mechanically fastened to a basket of the separator, the separator deck 120, or walls of the separator.

[0061] The channel 117 may be disposed either above or below the probe 140 or the reference probe 119. Referring to FIG. 12, channel 117 is disposed beneath the probe 140. According to this embodiment, the probe 140 is disposed within the channel 117, thereby ensuring slurry from the separator deck 120 is directed to the local volume and deposited on the probe 140. By collecting the filtered slurry in the channel 117, the amount of slurry entering the local volume and contacting probe 140 may also be more concentrated. In other words, the channel directly funnels or captures slurry filtered by the separator deck 120 to enter the local volume and be sensed by probe 140, thereby enhancing the signal produced by the probe 140. In other words, the signal of the probe 140 may be amplified and less noisy. Referring to FIG. 13, channel 117 may be disposed above the probe 140. As seen in FIG. 13, the channel 117 may collect the filtered slurry as the slurry passes through the separator deck 120. The collected slurry in the channel 117 may exit the channel 117 through the apertures and be deposited onto the probe 140 disposed below and onto

the flow-back pan 123. Thus, probe 140 receives a steadier and focused stream of filtered slurry.

[0062] The probe 140 may operate by measuring a property of a composition adjacent to the probe 140, where the composition may include at least one of a slurry, a component of a slurry (e.g., filtered slurry), and atmosphere (e.g., when a slurry does not contact the probe). The probe 140 generates a signal based on the measured property of composition adjacent to the probe 140. The signal may be sent from the probe 140 to an electronic control module (ECM) and/or database. Next a location of a beach on the separator deck may be determined based on the signal. According to some embodiments the ECM may automatically determine a location of the beach or a user may read the signal sent to the ECM and determine a location of the beach. Once a location of the beach has been determined the separator 100 may be adjusted to maintain a desired position of the beach. For example, if the beach is not in a desired position on the separator deck 110, 120, or 130 (e.g., if the beach is too close to the feed end or the discharge end of the separator) a flow rate of fluid to the separator 100, an angle of the separator deck 110, 120 or 130, an angle of the separator 100, or an angle of a basket 102 of the separator 100 may be adjusted to change a desired position of the beach. If the beach is near a desired beach location, then the ECM or operator may maintain current separatory conditions.

[0063] According to some embodiments, the method may include depositing a slurry on the first separator deck 110 disposed in a vibratory separator 100. As the slurry flows onto and along the length of the first separator deck 100, the slurry may be separated into a first filtered slurry component and a first solids component with a screen disposed in the separator deck. One having ordinary skill in the art will understand that monitoring a location of the beach may be performed continuously during the separation process so that the beach can be maintained in the desired location for more efficient separation of the solids from the slurry. According to other embodiments, the ECM or user may periodically check the location of the beach and adjust various parameters of the separator accordingly, e.g. angle of the separator deck, flow rate, etc. In some embodiments, monitoring the depth of the slurry around one or more probes within the vibratory separator may also be performed continuously or periodically during the separation process.

[0064] With reference to FIG. 4, as slurry is fed to the separator and deposited on a feed end of separator deck 110, a beach may form on the separator deck 110. If the length of a pool is shorter than the distance of probe 140 from a feed end 114 of the separator deck 110, then filtered slurry passing through the separator deck 110 may not enter the local volume of probe 140 and/or be deposited on probe 140. Throughout operation or periodically, the probe 140 may send a corresponding signal to an electronic control module (ECM) and/or a database. In response, the ECM may send instructions to the separator to adjust a separator parameter (*e.g.*, the angle of the deck, basket, or separator) or instructions to increase the flow rate to the separator (*e.g.* instructions sent to a valve upstream of the separator). Such adjustment to the separator 100 or slurry flow rate may thereby lengthen the pool bringing the beach location closer to probe 140. The probe may continuously or periodically monitor or measure the local area filtered slurry through the separator deck 110 to determine if the beach is located proximate the probe or in a desired position.

[0065] According to some embodiments, a second probe may be disposed beneath the separator deck 110. The second probe may send a second signal to the ECM. The ECM or a user may compare the signals from the first and second probes 140 to determine a location of the beach. For example, if the signals from the first and second probes 140 are similar to a control value, then the ECM may determine that a length of the pool is less than a desired beach. The separator 100 or flow rate may then be adjusted to lengthen the pool (*e.g.*, increasing fluid flow to the separator 100, decreasing an incline angle of a separator deck 110, increasing the vibratory force, changing the motion profile, and changing the mesh size of the screen). If the signal from the first probe 140 is different from the second signal from the second probe 140, then the beach may be located between the first and second probes 140, proximate a desired beach location. If the signals from the first and second probes 140 are not similar to the control value, then the length of the pool may be greater than the position of the second probe 140 and the separator 100 or flow rate may then be adjusted (*e.g.*, reducing fluid flow to the separator 100 or increasing an incline angle of a separator deck 110) to shorten the pool. One having ordinary skill in the art will understand that determining a location of the beach may be performed without a control value, for example, by comparing the first and second signals to each other.

[0066] One having ordinary skill in the art will understand that according to some embodiments, the determination to adjust a separator parameter or slurry flow rate to lengthen the pool may be made automatically by the ECM as well as by a user controlling the ECM. If the length of the pool is greater than or about equal to the distance of probe 140 from a feed end of the separator deck 110, then probe 140 may receive a steady deposit of filtered drilling fluid. The probe 140 may send a corresponding signal to the ECM. The ECM or a user may then determine whether to maintain current separator conditions, *i.e.* flow rate, angle of the separator deck 110, and/or angle of the basket 102, etc.

[0067] The measurement obtained by the probe 140 and corresponding signal may be, for example, a capacitance value of a slurry taken by a capacitance probe, a thermal conductivity value of a slurry taken by a thermal diffusivity probe, or any other property and corresponding probe known in the art. The corresponding signal may be an analog signal that indicates, for example, the capacitance measured by the probe 140 based on the amount of slurry deposited on the probe 140. The capacitance signal may be compared to a reference signal and/or control value to determine the amount of slurry deposited on the probe 140. In other embodiments, the corresponding signal may indicate a thermal conductivity of the local volume adjacent to the probe. Depending on the configuration of the probes, the signal sent by probe 140 may indicate how much slurry is present, if any, at a certain location along the length of the separator deck 110.

[0068] According to some embodiments, a reference probe 119 may be disposed proximate a feed end of the first separator deck 110 to measure a property of a local volume proximate a probe. The reference probe 119 may be a similar make and model to the measurement probe 140. The reference probe 119 may be smaller than the first probe 140 and may be disposed in a feed end chamber of the separator 100. A second signal may be sent from the reference probe 119 to the ECM. The second signal from the reference probe 119 may be used to determine a relative strength of a first signal from probe 140.

[0069] For example, a reference probe 119 may be disposed at a feed end 114 of a separator deck 110 having a probe configuration shown in FIG. 4. The reference

probe 119 may be disposed in a location where the reference probe 119 may be exposed to the feed slurry entering the separator deck or may be submerged in the feed slurry collected in a fluid collection cavity. As the slurry to be separated is deposited at the feed end of a separator 100, a pool may form on the first separator deck 110. As filtered slurry from the pool passes through the first separator deck 110, the reference probe 119 may receive a stream of slurry, thereby coating the reference probe 119 with slurry. Additionally, slurry may enter the local volume of probe 140. The reference signal from the reference probe 119 may be compared to the signal from probe 140. Thus, the reference probe 119 provides a reference signal, *i.e.* an example of a signal from the probe 140 if fully coated or in substantial contact with the wellbore fluid. By comparing the reference signal to the signal from probe 140, an operator may determine if slurry is entering the local volume of the probe 140 and being deposited on the probe 140, much like a digital (on/off) signal. For example, if the signal from probe 140 is similar to the reference signal, then the pool may be located above the probe 140. If the signal from probe 140 is similar to the control value (*i.e.*, signal from probe 140 indicating the probe 140 is exposed to air and/or no or minimal amounts of filtered slurry), then the beach may be not be located above the probe, and the pool does not extend past the location of the probe 140. Thus, the operator may determine a location of the beach and/or a subsequent action to adjust the location of the beach. One having ordinary skill in the art will readily understand that determining a location of the beach may be performed without a control value. For example, if the signal from probe 140 is significantly less than the reference signal, then it may be determined that no slurry or minimal amounts of slurry are entering the local volume adjacent to the probe.

[0070] According to some embodiments, the signal from the reference probe 119 may be compared to the signal from the probe 140 to determine the presence of slurry within the local volume at a given time, much like an analog signal. In other words, the signal from the probe 140 may have a value between the reference signal and the control value. For example, referring to FIGS. 7 and 9, filtered slurry passing through the separator deck 110 and falling on probe 140 will produce a measurement (signal) that is sent to the ECM. The reference probe 119 will similarly produce a reference signal that is sent to the ECM. While the signals from probes 140 in FIGS. 4 and 5

(*i.e.*, where the probes are positioned perpendicular to the direction of fluid flow along the separator deck) are analyzed to determine if fluid flow (*e.g.*, a significant amount) is being deposited on said probes 140, the signal from probes in embodiments of FIGS. 7 and 9 (*i.e.*, where the probes are positioned parallel to the direction of fluid flow along the separator deck) may be analyzed to determine how much of the probe 140 is exposed to a steady stream of filtered slurry. Because the signal from probe 140 is analog, the amplitude of the signal from the probe 140 may be proportional to the amount of slurry deposited along the length of the probe 140. For example, if the pool length covers 50% of the length of the probe 140, the resulting signal may be about half of the value of the reference signal.

[0071] Based on the desired beach location and position of probe 140 with respect to the desired beach location, a range of acceptable signal values for probe 140 may be determined. For example, referring to FIG. 7, if the desired beach location is 75% from a feed end 114 of the separator deck 110, because probe 140 spans the length of the deck, a range of acceptable signal values may be $75\% \pm 5\%$ of the reference signal. That is for a range of about 70% to 80% of a reference signal, the beach is near the desired beach location. If the signal from probe 140 is greater than the acceptable range, the separator 100 or flow rate may then be adjusted (*e.g.*, the flow rate may be decreased, the angle of the separator deck 110 increased, the vibratory force may be increased, the motion profile changed, and/or the mesh size of the screen changed) to shorten the pool. If the signal from probe 140 is less than the acceptable range, the separator or flow rate may then be adjusted (*e.g.* the flow rate may be increased, the angle of the separator deck 110 decreased, the vibratory force decreased, the motion profile changed, and/or the mesh size of the screen changed) to lengthen the pool. One having ordinary skill in the art will understand that the size of the acceptable range may vary according to various filtering conditions and applications. For example, the acceptable range may be a range of about 5%, 10%, or 20%.

[0072] The signal from probe 140 of FIG. 11 may be processed similarly to the above description with respect to the probes 140 in FIGS. 7 and 9. That is, based on the desired beach location and position of probe 140 with respect to the desired beach location, a range of acceptable signal values for probe 140 may be determined. For

example, referring to FIG. 11, if the desired beach location is 75% from a feed end of the separator deck 110, because the midpoint of probe 140 is about 75% from a feed end of the separator deck, a range of acceptable signal values may be $50\% \pm 5\%$ of the reference signal. That is for a range of about 45% to 55% of a reference signal, the beach is near the desired beach location. If the signal from probe 140 is greater than the acceptable range, the separator or flow rate may then be adjusted (*e.g.*, the flow rate may be decreased, the angle of the separator deck 110 increased, the vibratory force may be increased, the motion profile changed, and/or the mesh size of the screen changed) to shorten the pool. If the signal from probe 140 is less than the acceptable range, the separator or flow rate may then be adjusted (*e.g.* the flow rate may be increased or the angle of the separator deck 110 decreased, the vibratory motion changed, *e.g.*, vibratory force decreased and the motion profile changed, and/or the mesh size of the screen changed) to lengthen the pool.

[0073] Referring back to FIG. 5, according to some embodiments, a first probe 140 and a second probe 140 may be included to measure a position of the beach. The second probe 140 may send a third signal to the ECM and/or database. The first and third signals from the first and second probes may then be compared to the second signal from the reference probe to determine a location of the beach, as described below. According to some embodiments the third signal and the second signal may be compared to each other without a reference probe to determine a location of the beach.

[0074] As slurry is fed to the separator 100 and deposited on a feed end 114 of separator deck 110, a beach may form on the separator deck 110. Filtered slurry passing through the separator deck 110 entering the local volume and being deposited on the reference probe 119 will produce a reference signal that is sent to an ECM. Signals from the first and second probes 140 may also be sent to the ECM. The ECM or a user may compare the reference signal from the reference probe to the signals from the first and second probes 140 to determine a location of the beach. For example, if the signals from the first and second probes 140 are similar to a control value, then the ECM may determine that a length of the pool is less than a desired beach. The separator or flow rate may then be adjusted to lengthen the pool (*e.g.*, increasing slurry flow to the separator or decreasing an incline angle of a separator

deck 110). If the signal from the first probe 140 is similar to the reference signal, while the signal from the second probe 140 is similar to a control value, then the beach may be located between the first and second probes 140, proximate a desired beach location. If the signals from the first and second probes are similar to the reference signal, then the length of the pool is greater than the position of the second probe 140 and the separator or flow rate may then be adjusted (*e.g.*, reducing slurry flow to the separator or increasing an incline angle of a separator deck) to shorten the pool. One skilled in the art will understand that using more than one probe 140 to determine a location of the beach may be performed without a reference probe or control value.

[0075] Referring to FIG. 3, according to some embodiments, after slurry passes through the first separator deck 110, the first filtered slurry may be collected in a first flow-back pan 113. The first flow-back pan 113 may then direct the first filtered slurry to a second separator deck 120. The second separator deck will then separate the first filtered slurry into a second filtered slurry component and a second solid component. A third probe 140 disposed beneath the second separator deck 120 may measure a position of a second beach by measuring a slurry property of the second filtered slurry deposited thereon. The third probe 140 may then send a fourth signal to the ECM and a separator parameter, *e.g.* a flow rate or angle of inclination of the second separator deck 120 may be adjusted based on the fourth signal. According to some embodiments, the separator 100 may include a fourth probe 140 disposed beneath the second separator deck 120, such that the third probe 140 and the fourth probe 140 may determine a location of the second beach.

[0076] According to some embodiments, each probe including the reference probe 119 may have a channel 117 disposed proximate the probe. According to some embodiments, the probe may be disposed with in the channel 117 such that the probe detects a property of the slurry within the channel 117. The first filtered slurry may then exit the channel 117 through at least one aperture disposed in the channel 117 to a flow-back pan disposed beneath the probe or to another separator deck. According to other embodiments, the channel 117 may be disposed above the probe such that the first filtered slurry exiting the apertures are deposited on the probe. One having

ordinary skill in the art will understand that any number of probes may have a channel 117, while the remaining probes may not have a channel 117.

[0077] A reference probe may be disposed within or outside of a vibratory separator, where the reference probe is completely surrounded by the slurry being filtered in the vibratory separator. According to some embodiments of the present disclosure, a vibratory separator may include at least one probe therein, while a reference probe may be upstream, downstream or inside the vibratory separator in a location where a slurry surrounds the entire reference probe. When surrounding a reference probe with the same slurry that is filtered through a vibratory separator or a sample of representative slurry filtered through the vibratory separator, the reference probe may be referred to herein as being associated with the vibratory separator, whether or not the reference probe is disposed inside or outside of the vibratory separator.

[0078] For example, FIG. 14 shows a diagram of a vibratory separator 400 according to embodiments of the present disclosure having at least one probe 470 therein and an associated reference probe 480 disposed in a fluid collection cavity 409 within the vibratory separator 400. The vibratory separator 400 includes three separator decks or levels 401, 402, 403 and two flow back pans 404, 405 in an alternating arrangement with the separator decks, where the flow back pans 404, 405 route drilling fluid 440 between the separator decks 401, 402, 403. Other separators may include a different number of separator decks (e.g., one, two, three, etc.) and flow back pans (e.g., zero, one, two, etc.).

[0079] During separatory operations, a slurry having a liquid-solid mixture such as drilling fluid 440 with cuttings therein may be deposited through an inlet 407 of the vibratory separator 400 onto a feed end of the vibratory separator 400. The liquid-solid mixture may form a “pool” comprising primarily the liquid-solid mixture on the feed end of the vibratory separator 400. A sample of the drilling fluid 440 flows into and fills the fluid collection cavity 409, such that the entire length of the reference probe 480 is fully immersed in the drilling fluid 440. One or more motors 450 mounted to the vibratory separator 400 may provide motion, e.g., vibratory or elliptical motion, to the separator 400, to shake the separator and contents therein. As the liquid-solid mixture progresses across the top separator deck 401, fluid 440 may

drain through a screen disposed in the top separator deck 401 leaving primarily solid matter to be discarded at a discharge end 406. The fluid 440 may then flow down a first flow back pan 404 and onto the middle separator deck 402. As the fluid 440 drains through a screen disposed in the middle separator deck 402, additional solid matter may remain on top of the screen, which may be discarded. The fluid 440 may then flow down a second flow back pan 405 and onto the bottom separator deck 401. As the fluid 440 drains through a screen disposed in the bottom separator deck 403, any remaining solid matter may remain on top of the screen, which may be discarded, and the fluid 440 may exit through an outlet 408 of the separator.

[0080] In the embodiment shown, two probes 470 are disposed within the vibratory separator 400, each probe 470 disposed on (*i.e.*, above) a separator deck 402, 403 extending in a vertical direction from the separator deck 402, 403. However, in other embodiments, one probe or more than one probe may be disposed within a vibratory separator, for example, directly above one or more separator decks, in the distribution tank of a vibratory separator (where the slurry is introduced to the vibratory separator, and, in the instance of a multideck vibratory separator, where slurry may drain from a preceding deck before being introduced to the next deck). The separator decks 402, 403 are angled with respect to a horizontal plane extending through the vibratory separator. According to some embodiments of the present disclosure, one or more separator decks may be horizontally positioned within a vibratory separator (*i.e.*, parallel with a horizontal plane extending through the vibratory separator), and/or one or more separator decks may be positioned at a slope from a horizontal plane extending through the vibratory separator, for example, ranging from less than 0 degrees to about -8 degrees. Probes mounted to a sloped or angled separator deck may extend obliquely from the separator deck (*e.g.*, the probes 470 extending obliquely from sloped separator decks 402, 403), and probes mounted to a horizontal separator deck may extend perpendicularly from the separator deck, such that the probes are parallel with a depth dimension of the drilling fluid 440 (*i.e.*, in a vertical direction).

[0081] The reference probe 480 and the probes 470 are capacitance probes, where the measured capacitance is a function of the drilling fluid 440 properties and the amount of the probe length covered by the fluid 440. By completely immersing the reference

probe 480 in a representative sample of the drilling fluid 440 (i.e., having the entire length of the probe 480 covered by the drilling fluid 440), a baseline or reference capacitance may be measured for a known probe length, i.e., the total length of the reference probe 480. Further, because the reference probe 480 is immersed in a representative sample of the same fluid 440 being measured by probes 470, the same fluid properties may be assumed for calculating the length of probes 470 covered by the fluid 440. Thus, the length of probes 470 covered by fluid 440 (i.e., the depth of the drilling fluid 440 around probes 470) may be calculated by comparing the capacitance reading from probes 470 to the capacitance reading from reference probe 480.

[0082] According to embodiments of the present disclosure, a length of a probe covered by a slurry (e.g., a drilling fluid), and thus, the depth of the slurry around the probe, may be calculated from the capacitance measured by the probe and the capacitance measured by an associated reference probe, when the entire length of the reference probe is covered with a representative sample of the same slurry being measured by the probe (i.e., the slurry around the reference probe has substantially the same or similar properties as the slurry around the probe). In other words, by comparing the capacitance of the slurry along a known probe length (the entire length of the reference probe) with the capacitance of the slurry along an unknown length of the probe, where the slurry around the reference probe shares the same or substantially similar properties with the slurry around the probe, the length of the probe covered with the slurry (and thus the slurry depth around the probe) may be calculated based on the function that the measured capacitance is related to the slurry properties and the amount of the probes' length covered by the slurry.

[0083] FIG. 15 shows another example of a vibratory separator 500 according to embodiments of the present disclosure having at least one probe 571, 572, 573 therein and an associated reference probe 580 disposed outside the vibratory separator 500. The probes 571, 572, 573 are disposed above and extend vertically from each of the separator decks 501, 502, 503 within the vibratory separator 500. The reference probe 580 is disposed in a conduit 590 leading into the vibratory separator 500 (upstream of the vibratory separator). The reference probe 580 may be positioned vertically,

angled or horizontally within a representative sample of the slurry, such that the reference probe 580 is completely immersed in the slurry.

[0084] As drilling fluid 540 flows through the inlet conduit 590 and into the vibratory separator 500, the drilling fluid immerses and completely surrounds the associated reference probe 580 and flows onto a top separator deck 501. Depending on, for example, the slope of the top separator deck 501, the location of the first probe 571 (e.g., the distance away from the inlet side of the vibratory separator), the flow rate and composition of the drilling fluid 540, and how fast the drilling fluid 540 separates and drains through the top separator deck 501, the drilling fluid 540 may then flow to a depth 545 around the first probe 571. By comparing the capacitance measured from the associated reference probe 580 and the capacitance measured from the first probe 571, the length of the first probe 571 that is covered by the drilling fluid 540 (and thus the depth 545 of the drilling fluid 540 around the first probe 571) may be calculated. The drilling fluid 540 may then drain through the top separator deck 501 onto a first flow back pan 504, which directs the drilling fluid 540 to an inlet side of the middle separator deck 502. A second probe 572, located a distance from the inlet side, is disposed on and extends vertically from the middle separator deck 502. As the drilling fluid 540 flows up the middle separator deck 502, the second probe 572 may measure any change in capacitance, thereby indicating the depth of the drilling fluid 540 around the second probe 572. The drilling fluid 540 may then drain through the middle separator deck 502 onto a second flow back pan 505, which directs the drilling fluid 540 to an inlet side of the bottom separator deck 503. A third probe 573, located a distance from the inlet side, is disposed on and extends vertically from the bottom separator deck 503. As the drilling fluid 540 flows up the bottom separator deck 503, the third probe 573 may measure any change in capacitance, thereby indicating the depth of the drilling fluid 540 around the third probe 573. The drilling fluid 540 may then drain through the bottom separator deck 503 and out the outlet 508 of the vibrator separator 500.

[0085] FIG. 16 shows another example of a vibratory separator 600 according to embodiments of the present disclosure having at least one probe 670 therein and an associated reference probe 680 disposed outside the vibratory separator 600. Two probes 670 are disposed above and extend vertically from each of the separator decks

601 within the vibratory separator 600. The reference probe 680 is disposed in a conduit 690 leading slurry 640 out of the vibratory separator 600, where the conduit 690 is downstream of the vibratory separator. By placing two or more probes 670 along each separator deck 601, the depth of slurry 640 along each separator deck may be monitored, including, for example, the progression or regression of a slurry pool, location of a beach region, and the rate at which the slurry is filling one or more regions of the vibratory separator.

[0086] Further, the capacitance of one or more probes may be measured continuously to provide continuous monitoring of the depth of the slurry in the local volume around each probe. The capacitance measured from an associated reference probe may also be measured continuously or may be measured periodically to account for any changes in slurry properties that may occur during separatory operations. For example, the capacitance of a probe may be measured continuously and the capacitance of an associated reference probe may be measured continuously or periodically, where an increase in capacitance measured from the probe may indicate in real time, or close to real time (including any delay from signal transmission), that the slurry depth has increased, and a decrease in capacitance measured from the probe may indicate that the slurry depth has decreased.

[0087] In some embodiments, more than one associated reference probe may be used to provide a baseline or reference capacitance. In embodiments having more than one associated reference probe, the associated reference probes may be disposed in fluid collection cavities located upstream, downstream, and/or inside the vibratory separator. Further, in embodiments having more than one associated reference probe, different reference probes may provide a reference capacitance for different probes within the vibratory separator, or the capacitance measurements for more than one associated reference probe may be averaged to provide a reference capacitance for one or more probes within the vibratory separator. For example, an associated reference probe may be positioned upstream from a vibratory separator (in a location where the entire reference probe may be immersed in the slurry) and an associated reference probe may be positioned downstream from a vibratory separator (in a location where the entire reference probe may be immersed in the slurry), where the upstream reference probe may provide a reference capacitance for one or more probes

within the vibratory separator relatively closer to the vibratory separator inlet, and the downstream reference probe may provide a reference capacitance for one or more probes within the vibratory separator relatively closer to the vibratory separator outlet. In another example, at least one associated reference probe may be located within a vibratory separator (e.g., in a channel or fluid collection chamber) along or proximate to one or more separator decks having at least one probe thereon, and/or an associated reference probe may be located upstream and/or downstream of the vibratory separator. By collecting a pool or sample of slurry large enough to immerse a reference probe (e.g., in a channel along the side of or beneath a separator deck or other fluid collection cavity) proximate to a region having a probe for measuring slurry depth, the slurry properties of the slurry surrounding the reference probe may more closely match the properties of any slurry around the probe, and thus the slurry depth calculations may be more accurate.

[0088] For example, FIG. 17 shows a vibratory separator 700 according to embodiments of the present disclosure that includes a plurality of separator decks 701, 702, 703, a plurality of probes 771, 772 and multiple associated reference probes 781, 782. The reference probes 781, 782 are disposed in channels 709 along the inlet side of separator decks 702, 703, where the channels 709 collect slurry 740 passing through the vibratory separator 700 to completely immerse the reference probes 781, 782 in representative samples of slurry 740 that flow across each separator deck 702, 703. The capacitance measured by the probes 771 disposed along a second separator deck 702 may be compared with the capacitance measured by the associated reference probe 781 disposed at the inlet side of the second separator deck 702 to calculate the depth of the slurry 740 surrounding the probes 771. Similarly, the capacitance measured by the probes 772 disposed along a third separator deck 703 may be compared with the capacitance measured by the associated reference probe 782 disposed at the inlet side of the third separator deck 703 to calculate the depth of the slurry 740 surrounding the probes 772.

[0089] Referring now to FIG. 18, another example of a separator 100 according to embodiments of the present disclosure is shown. The separator 100 includes a plurality of shaker decks 110, 120, 130, a reference probe disposed in a conduit 190 leading into the separator (upstream of the vibratory separator), and probes 140, 160

disposed a distance away from the reference probe 180 and within the separator 100. The reference probe 180 may be positioned vertically, angled or horizontally within a representative sample of slurry 840, such that the reference probe 180 is completely immersed in the slurry 840. Further, although the reference probe 180 is shown in a conduit 190 at a feed end of the separator, the reference probe may be in other locations having a representative sample of the slurry. The probes 140, 160 are disposed in fluid collection systems, such as conduits 150 and 170, respectively, and are positioned to determine a depth of the slurry 840 as it flows through the separator. In the embodiment shown, reference probe 160 may be positioned within the separator to measure the depth of slurry 840 at the feed end of a second separator deck 120, and reference probe 140 may be positioned within the separator to measure the depth of the slurry 840 at the feed end of a third separator deck 130. However, in other embodiments, one or more probes may be positioned at different locations along different separator decks, as described above, to determine the depth of a slurry flowing through a separator at the different locations.

[0090] Based on the calculated slurry depth (from the capacitance measured from one or more probes and associated reference probes), the conditions of the vibratory separator, for example, the angle of one or more separator decks, the flow rate of the slurry, and/or the number of vibratory separators running in parallel, may be altered or maintained to maintain a certain slurry depth range and/or a desired beach location.

[0091] According to embodiments of the present disclosure, a method for monitoring the movement of slurry through a vibratory separator may include adding a slurry into the vibratory separator, measuring a property (e.g., capacitance) of a local volume of the slurry surrounding a reference probe, monitoring a region proximate a first probe within the vibratory separator, and comparing measurements from the reference probe and the first probe to determine the movement of the slurry. Determining the movement of the slurry may include determining the location of one or more beaches or determining the depth of the slurry in selected regions of the vibratory separator, as discussed above.

[0092] For example, in some embodiments, the location of a beach in a vibratory separator may be determined by measuring the capacitance of a representative sample

of slurry surrounding a reference probe and monitoring the capacitance of the region proximate a first probe, where the first probe is positioned in or proximate to a desired beach region within the vibratory separator. By comparing the capacitance of the associated reference probe with the capacitance of the first probe, the depth of the slurry around the first probe may be calculated. The location of the beach may then be calculated using the calculated depth of the slurry around the first probe and the slope of the surface on which the first probe is mounted (and trigonometry equations for calculating the lengths of a triangle).

[0093] In some embodiments, a method of determining the location of the beach may include using at least two probes and an associated reference probe. A property (e.g., capacitance, as described above) of a local volume of slurry or region around the at least two probes and the reference probe may be measured to determine the location of the slurry, and thus the location of the beach. For example, a reference probe may be completely immersed in a representative sample of slurry, and at least two probes may be disposed in or proximate to a desired beach location of the slurry within a vibratory separator. The associated reference probe may measure the capacitance of the representative slurry sample surrounding the reference probe, and the at least two probes may measure the capacitance of the region around the probes. By comparing the capacitance of the associated reference probe with the capacitance of the probes, the depth of the slurry around the probes may be calculated, as discussed above. The location of the beach may then be calculated using the calculated depth of the slurry around the probes, and optionally, the slope of the surface on which the probes are mounted (and trigonometry equations for calculating the lengths of a triangle). For example, a first probe of the at least two probes may be disposed on a separator deck within the vibratory separator, in or proximate the desired beach region, and a second probe of the at least two probes may be disposed between the first probe and a discharge end of the separator deck. The measurements of the first and second probes may be compared to determine and monitor the location of the beach, for example, if the slurry has reached the second probe, if the slurry is between the first and second probe, or if the slurry has reached the first probe.

[0094] One of ordinary skill in the art will appreciate that various configurations of probes may be used with a vibratory separator to determine a slurry level and/or a

beach location on one or more decks of a vibratory separator without departing from the scope of embodiments disclosed herein. For example, one or more probes above a separator deck may be used in combination with or in the alternative to one or more probes below the separator deck. Further, each deck of a single vibratory separator may have a different configuration (number, location, orientation) of probes. Further, one or more reference probes may also be used with a vibratory separator having one or more probes, the reference probe being positioned upstream, downstream, or proximate an inlet of one or more separator decks of the vibratory separator.

[0095] Depending on the location of the slurry (e.g., location of a beach along a separator deck, depth of a slurry along one or more surfaces, etc.), the conditions of the vibratory separator may be maintained or adjusted to have the slurry in a desired location. For example, to keep the location of a beach in a desired region, the conditions of the vibratory separator (e.g., slope of one or more separator decks, flow rate of the slurry, vibratory motion (e.g., vibratory force, speed and/or type), number of vibratory separators operating in parallel, etc.) may either be maintained, for example, if the calculated beach location is within the desired beach region, or may be adjusted, for example, if the calculated beach location is outside of the desired beach region.

[0096] Although the preceding description has been described herein with reference to particular means, materials and embodiments, it is not intended to be limited to the particulars disclosed herein. Rather, it extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims.

CLAIMS

1. An apparatus comprising:
 - a screen capable of separating solids from a slurry having a liquid portion and a solid portion; and
 - a first probe disposed beneath the screen to determine a position of a beach between a feed end and a discharge end of the screen, the beach being a transition where a substantial majority of the liquid portion of the slurry terminates.
2. The apparatus of claim 1, wherein the beach comprises a region where the slurry transitions to a composition having a substantial majority of the solid portion.
3. The apparatus of claim 1, further comprising a second probe disposed beneath the screen, the second probe located between the first probe and the discharge end of the screen.
4. The apparatus of claim 1, further comprising a reference probe configured to measure a dielectric constant of the slurry.
5. The apparatus of claim 1, further comprising a channel disposed below the screen and capable of collecting the slurry, wherein the first probe is disposed in the channel or below the channel.
6. The apparatus of claim 1, further comprising a reference probe configured to determine a capacitance of the slurry proximate the feed end of the screen and the first probe is configured to determine a capacitance at a location along the screen between the reference probe and the discharge end of the screen to determine if the slurry is at the location.
7. An apparatus comprising:
 - a vibratory separator;
 - a reference probe disposed in a fluid collection system coupled to the vibratory separator to determine a property of a slurry in the fluid collection system; and
 - at least one probe disposed within the vibratory separator to determine the property at a location away from the reference probe.

8. The apparatus of claim 7, wherein the reference probe is disposed above a separator deck of the vibratory separator.
9. The apparatus of claim 7, wherein the reference probe and the at least one probe are capacitance probes.
10. A method comprising:
 - providing a slurry to a vibratory separator;
 - measuring a property of a portion of the slurry adjacent to a reference probe;
 - measuring a property of a composition adjacent to a first probe within the vibratory separator; and
 - comparing measurements from the reference probe and the first probe to determine a position of the slurry.
11. The method of claim 10, wherein the composition adjacent to the first probe comprises one of the slurry, a liquid portion of the slurry, or atmosphere.
12. The method of claim 10, further comprising determining a location of a beach along a first separator deck within the vibratory separator based on detection of the slurry in the composition adjacent to the first probe, wherein the first probe is beneath the first separator deck.
13. The method of claim 12, wherein determining the location of the beach further comprises:
 - measuring the property of a composition adjacent to a second probe, the second probe disposed between the first probe and a discharge end of the first separator deck; and
 - comparing the measurements of the second probe and the first probe.
14. The method of claim 12, further comprising maintaining conditions of the vibratory separator or adjusting the conditions of the vibratory separator to maintain the location of the beach within a distance from a feed end of the first separator deck.
15. The method of claim 14, wherein the distance ranges between 50 percent and 95 percent of a length of the first separator deck.

16. The method of claim 10, further comprising adjusting at least one condition within the vibratory separator based on the first probe measurement, the at least one condition selected from the group consisting of a flow rate of the slurry to the vibratory separator, a separator deck angle, a vibratory force, a vibratory speed, and a vibratory motion type.
17. The method of claim 10, further comprising:
 - providing the slurry on a first screen disposed in the vibratory separator;
 - directing a filtered slurry to a second screen located below the first screen;
 - measuring the property of a composition adjacent to a second probe disposed beneath the second screen to determine a position of the filtered slurry along the second screen; and
 - adjusting at least one condition selected from a flow rate or an angle of the second screen based on the second probe measurement.
18. The method of claim 10, further comprising determining a depth of the slurry around the first probe, wherein the first probe extends vertically above a separator deck of the vibratory separator.
19. The method of claim 10, wherein the measuring the property of the portion of the slurry adjacent to the reference probe comprises measuring a capacitance of the portion of the slurry adjacent to the reference probe, and the measuring of the property of the composition adjacent to the first probe comprises measuring a capacitance of the composition.
20. The method of claim 10, further comprising:
 - collecting a filtered slurry in a channel disposed beneath the first probe or above the first probe, wherein the first probe detects a property of the filtered slurry in the channel.

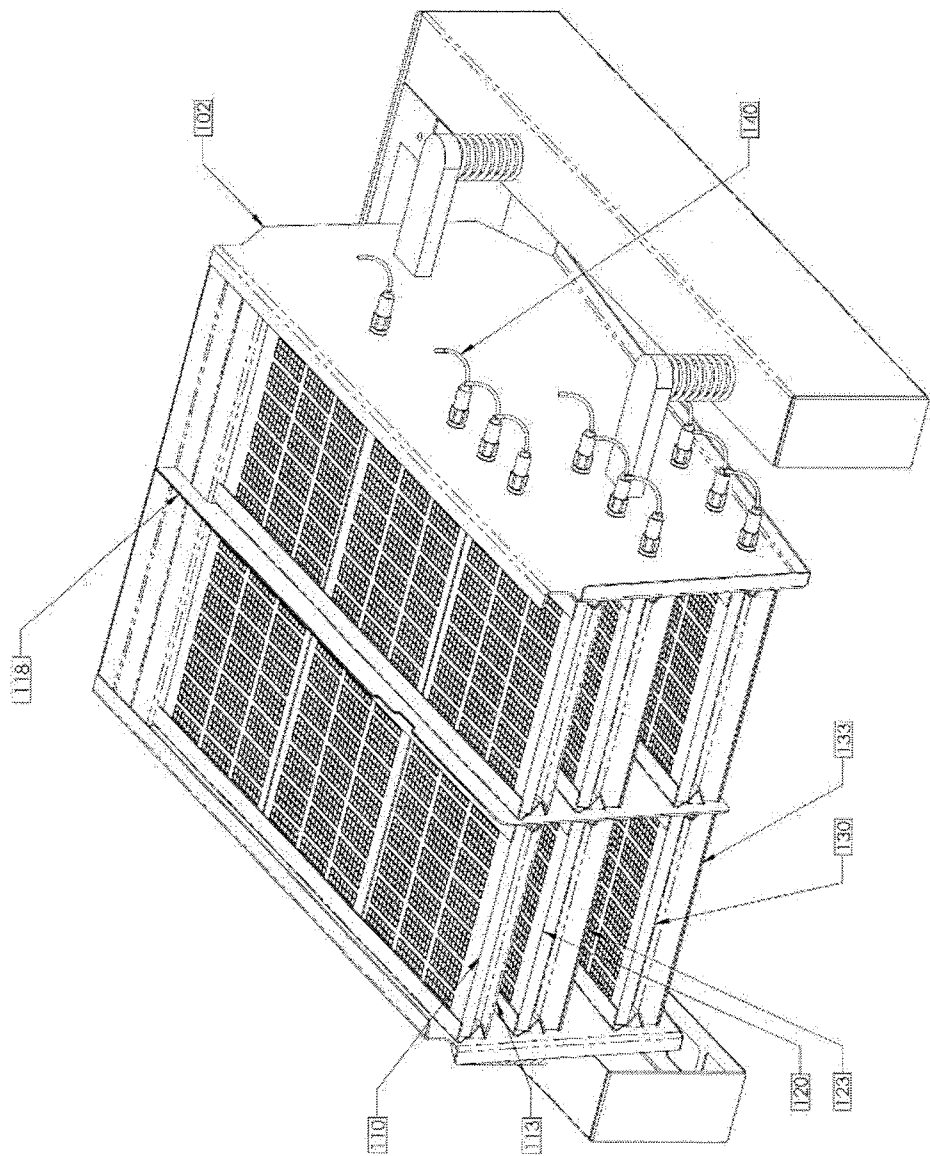


FIG. 1

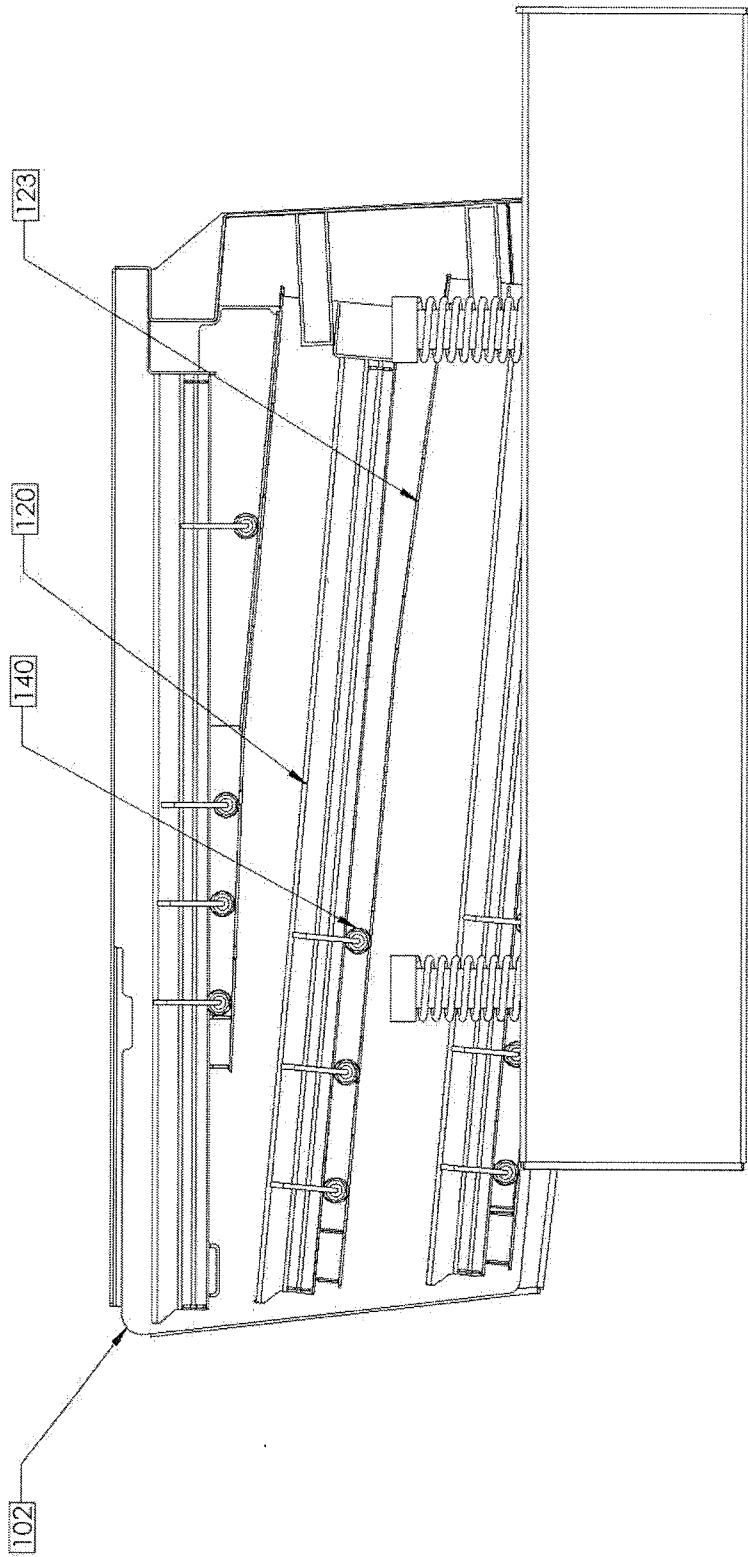
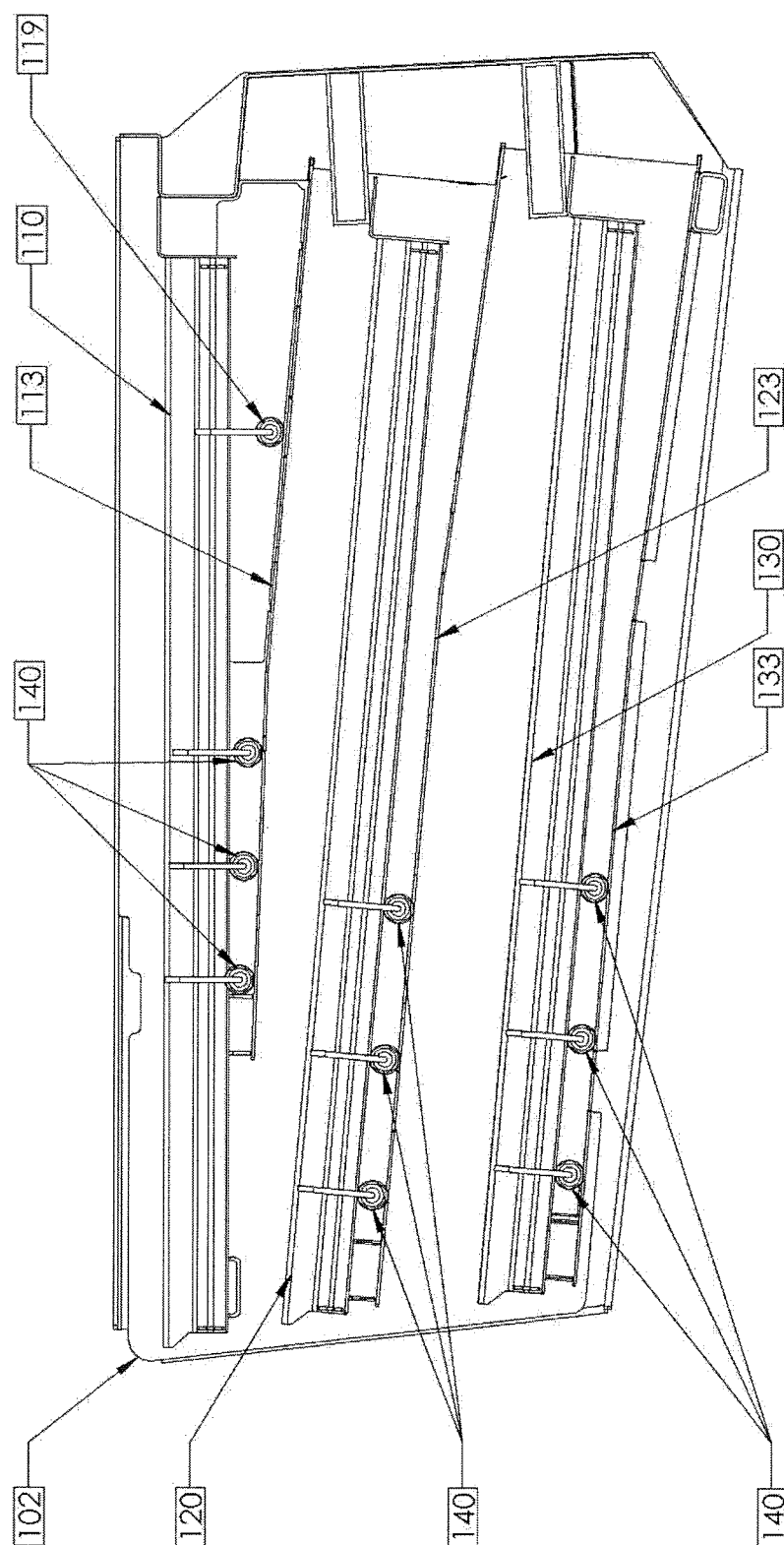
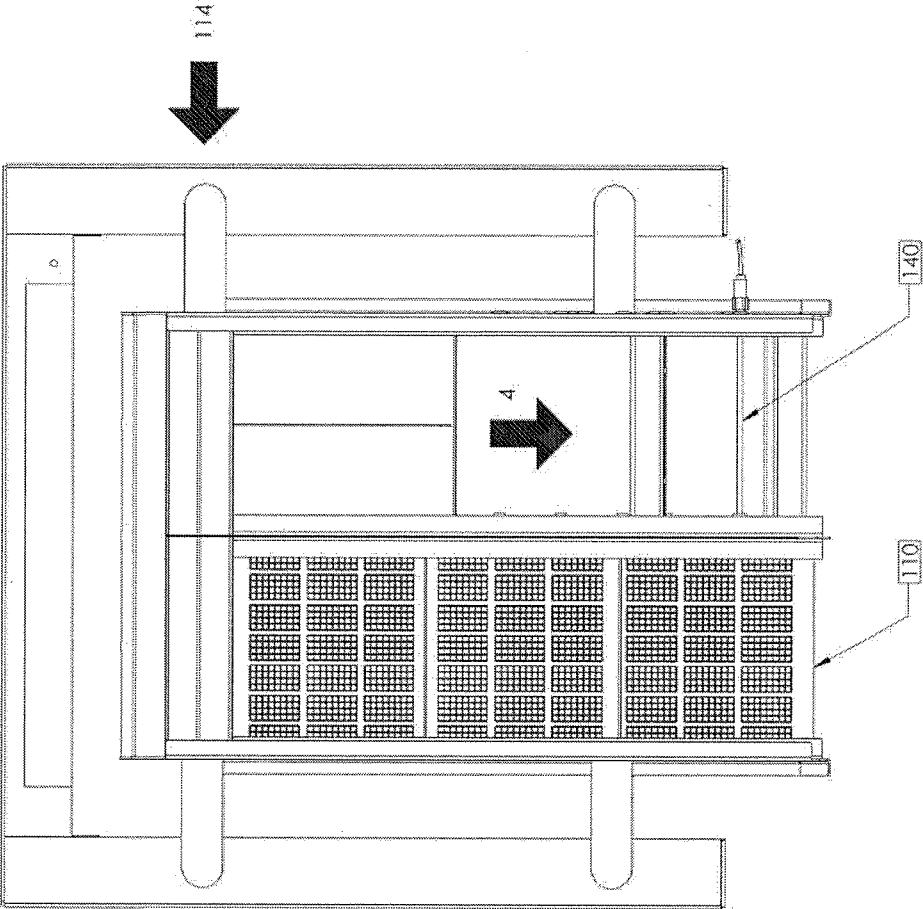


FIG 2

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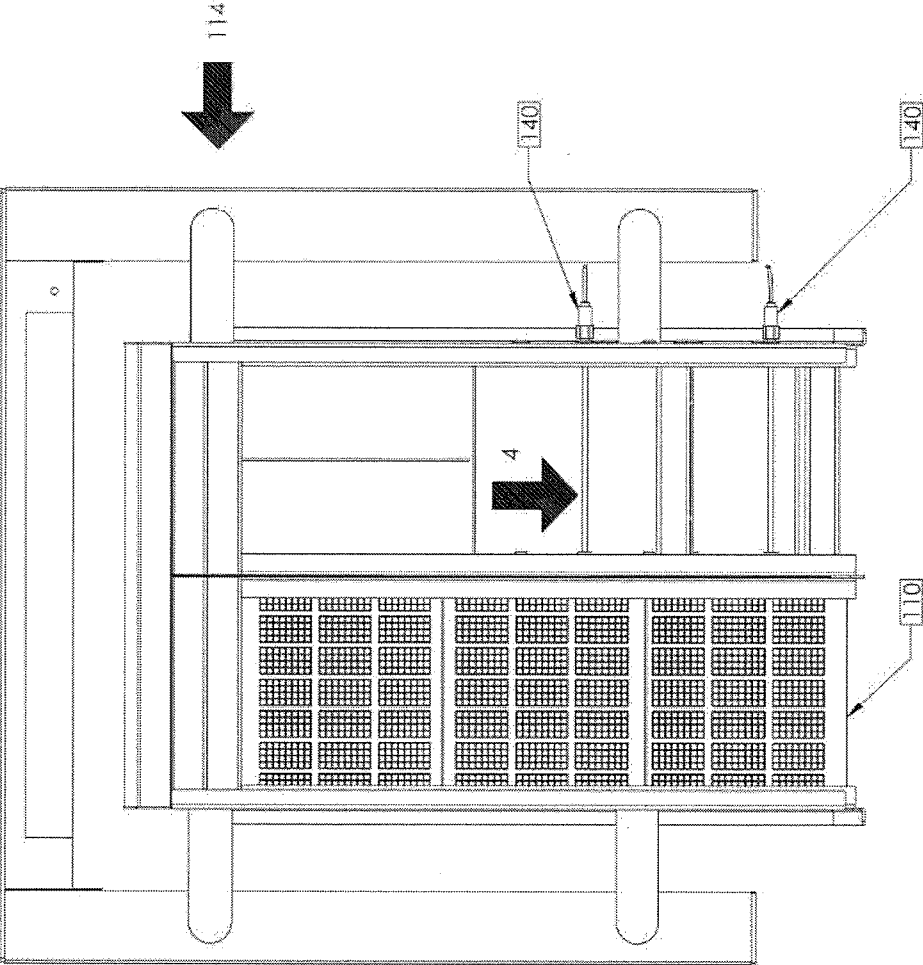
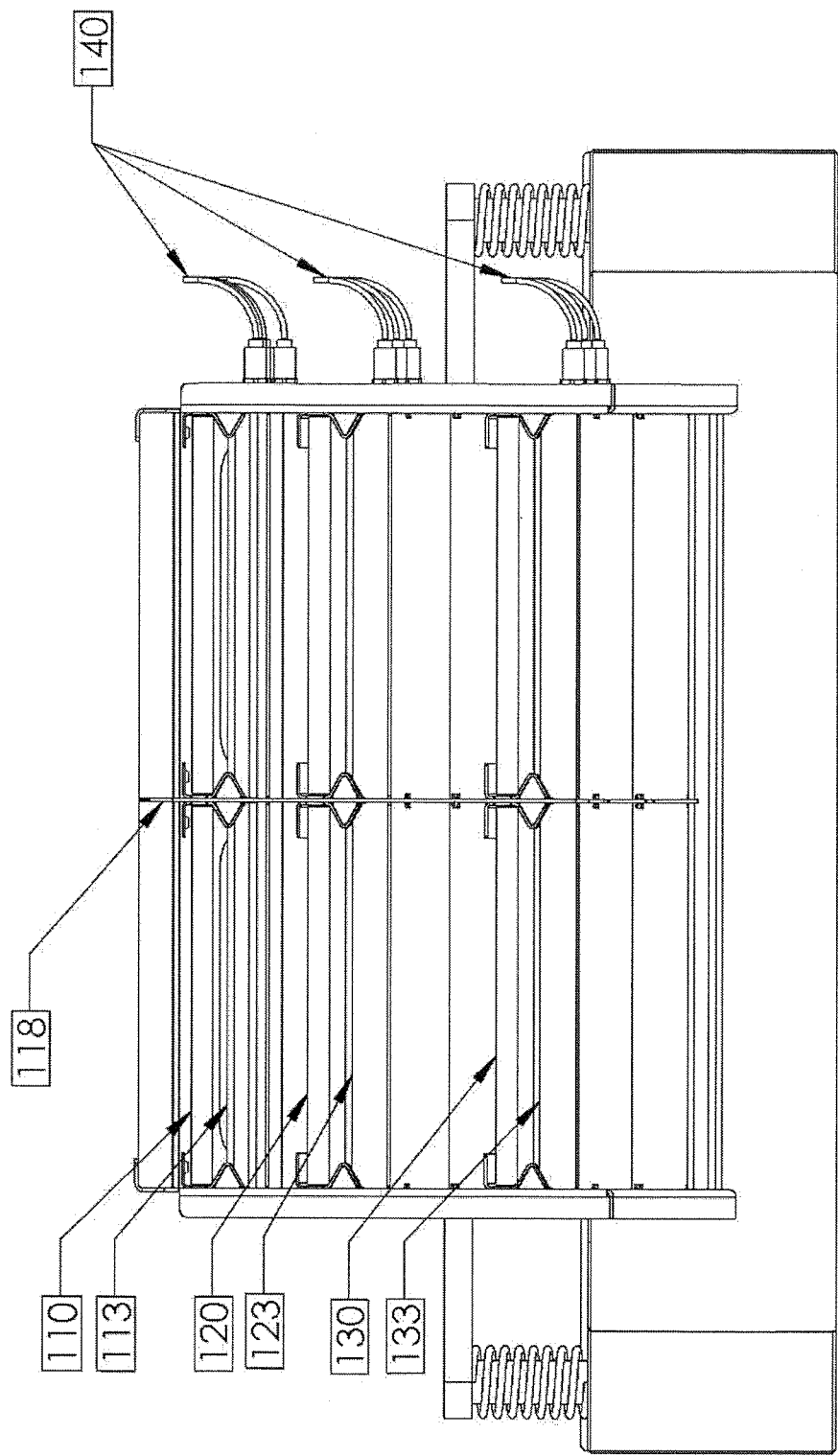
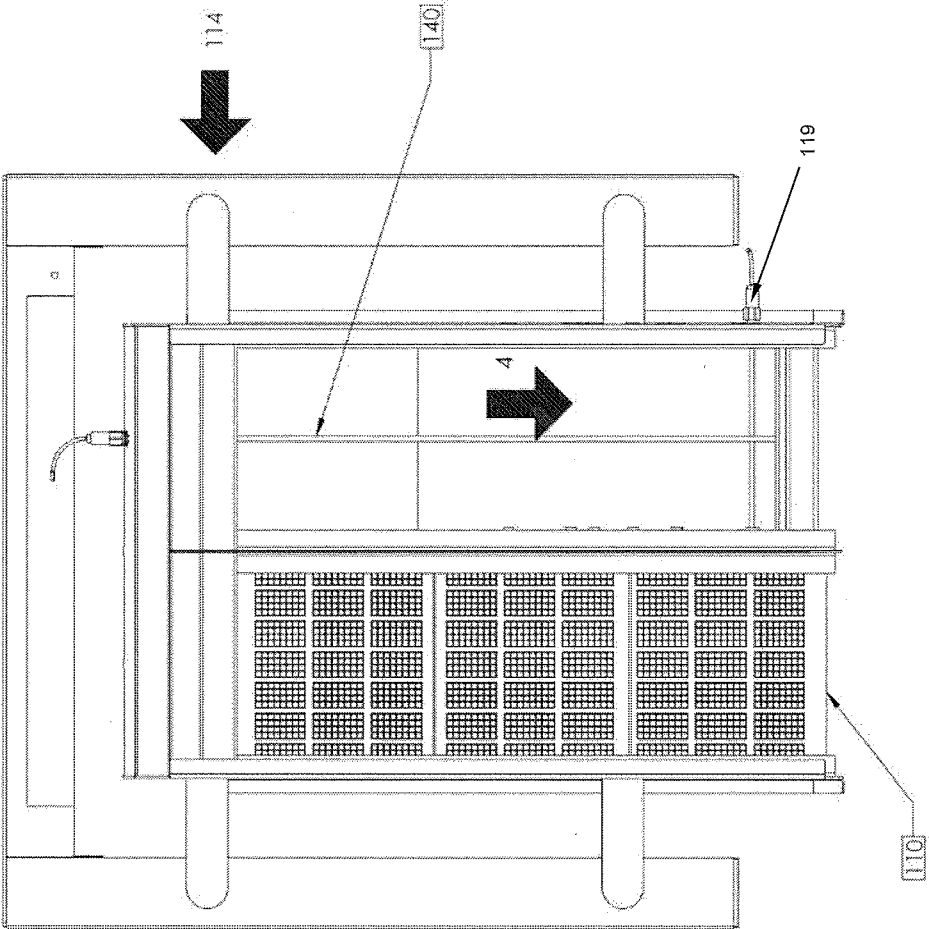


FIG 5



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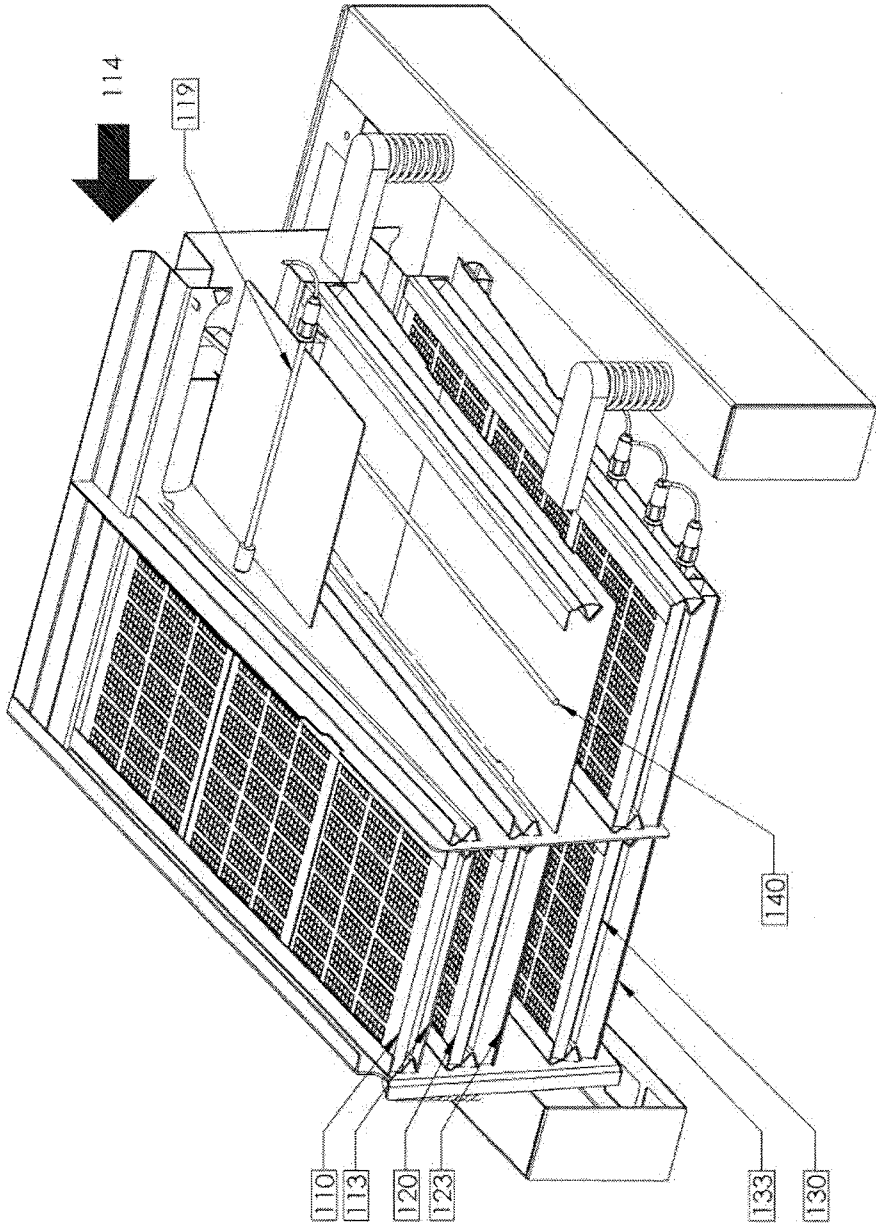
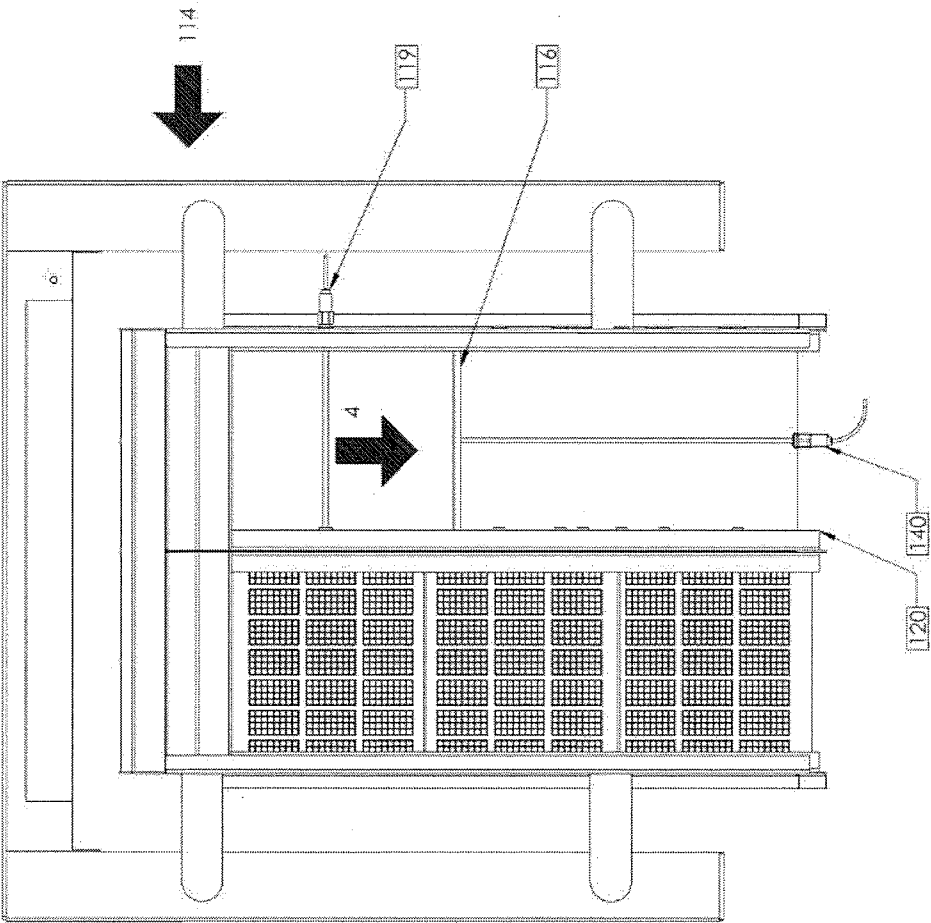
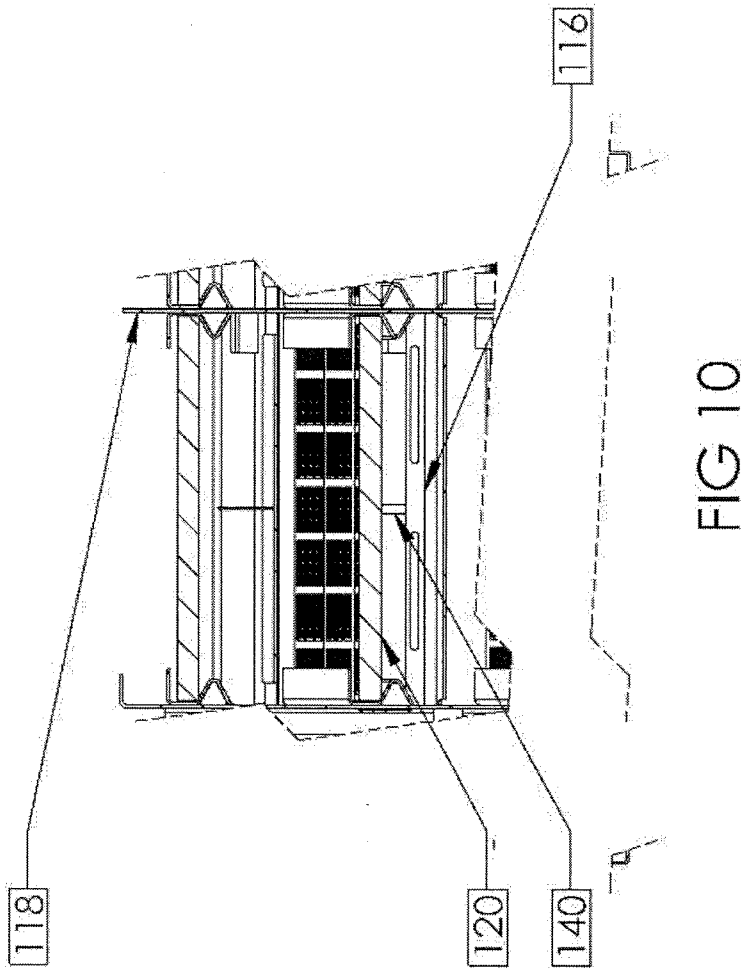


FIG 8

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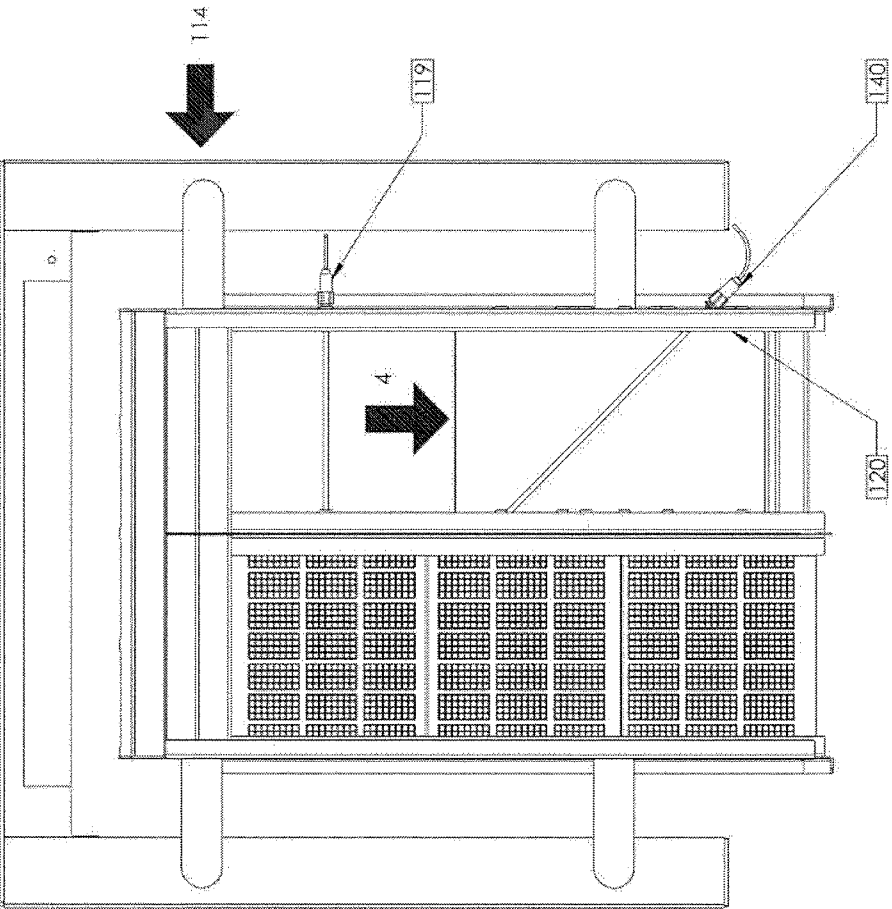
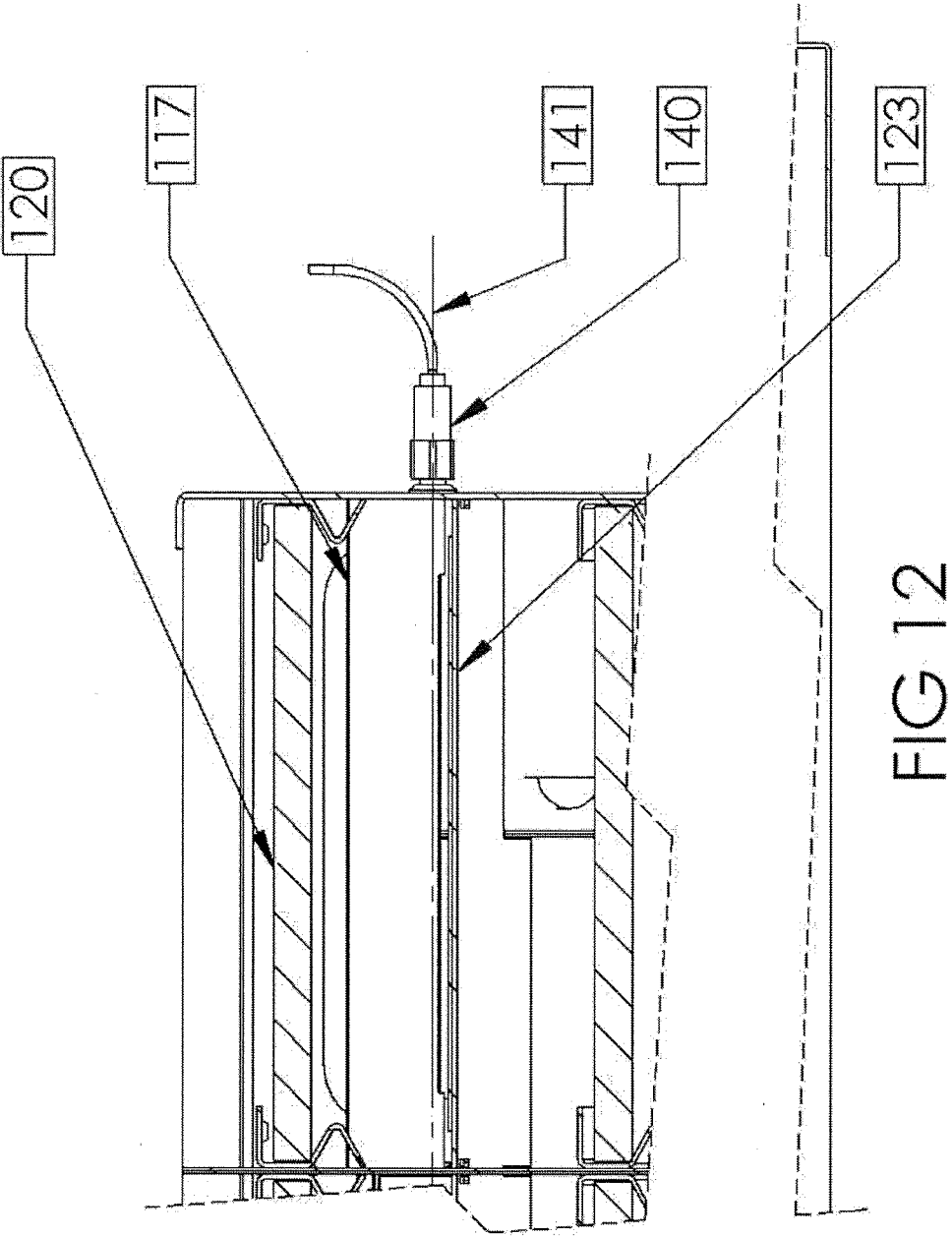


FIG 11

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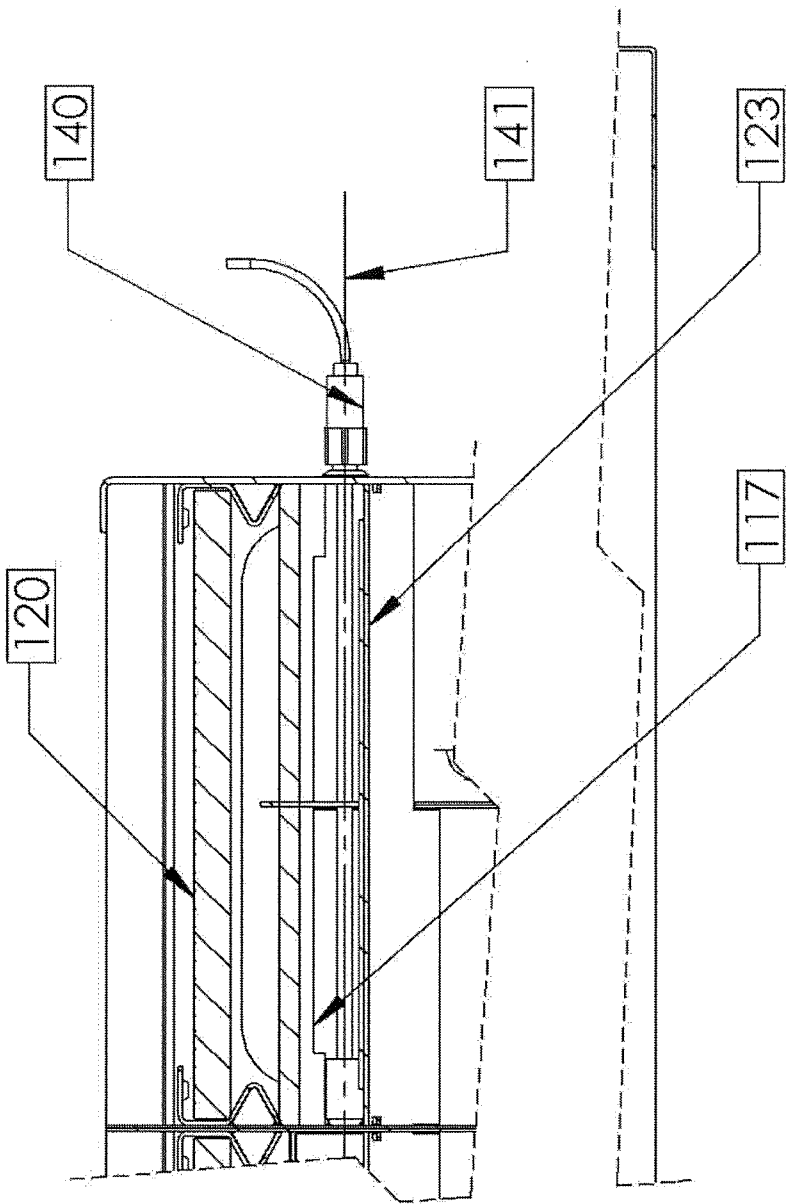


FIG 13

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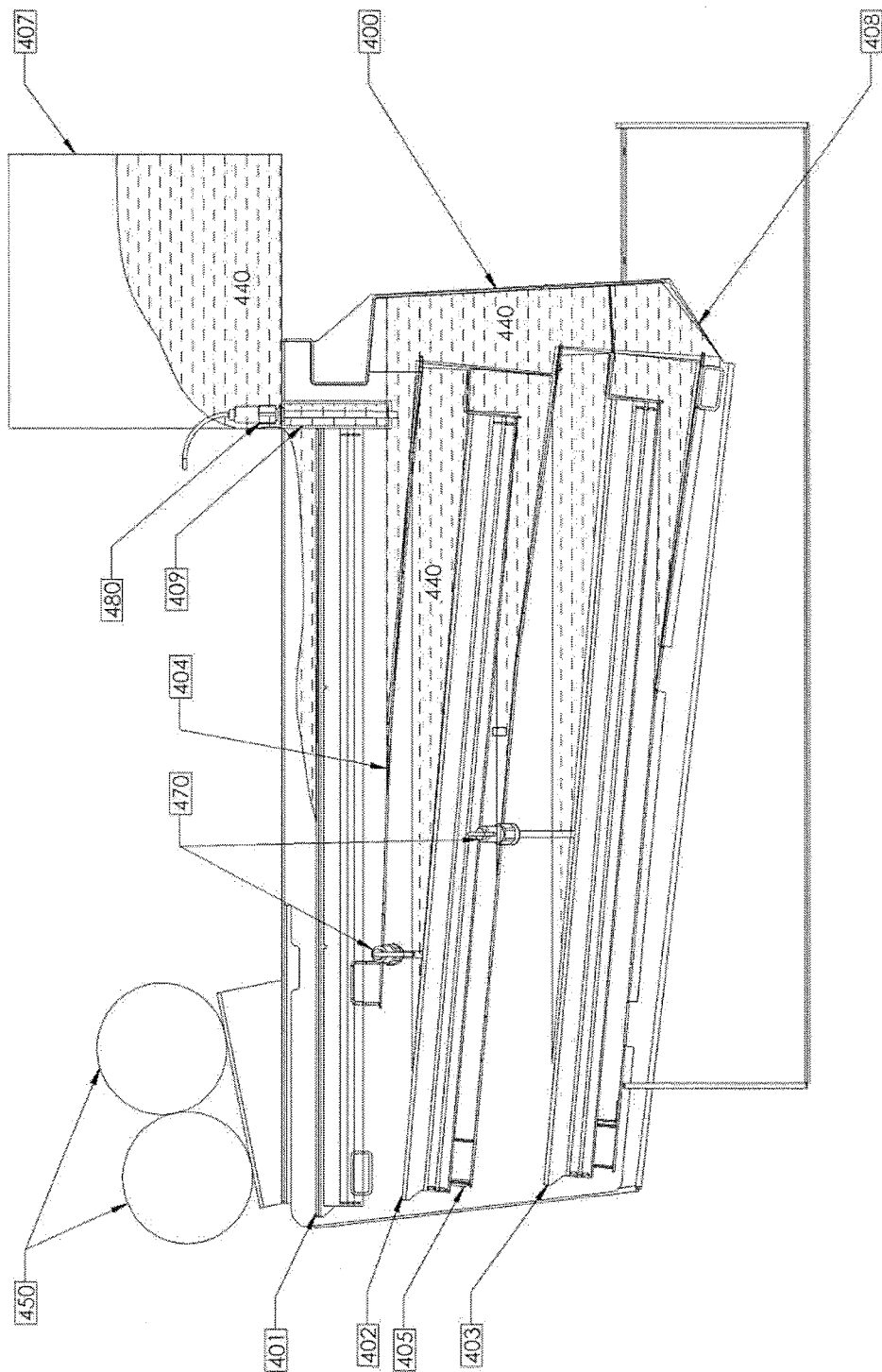


FIG. 14

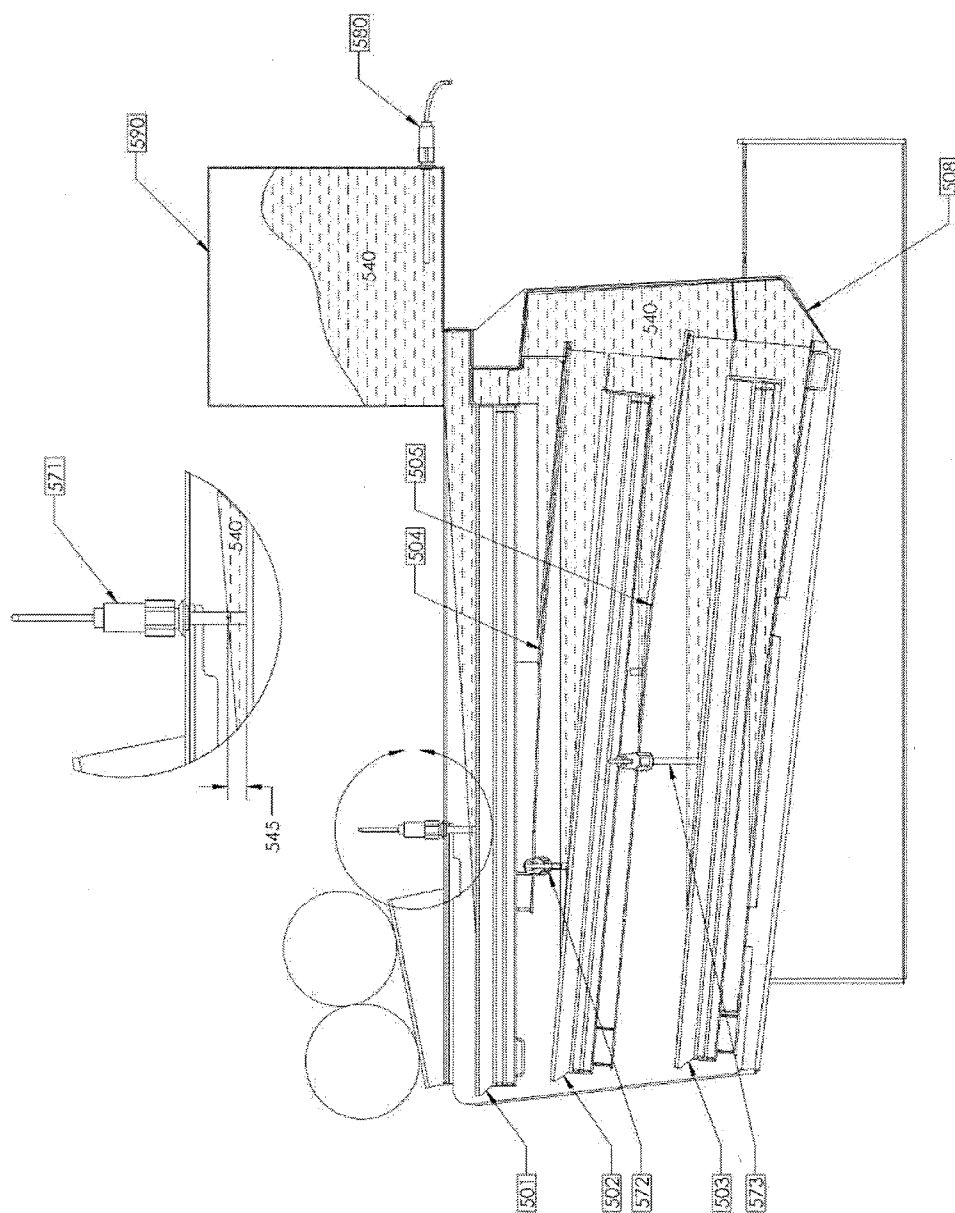


FIG. 15

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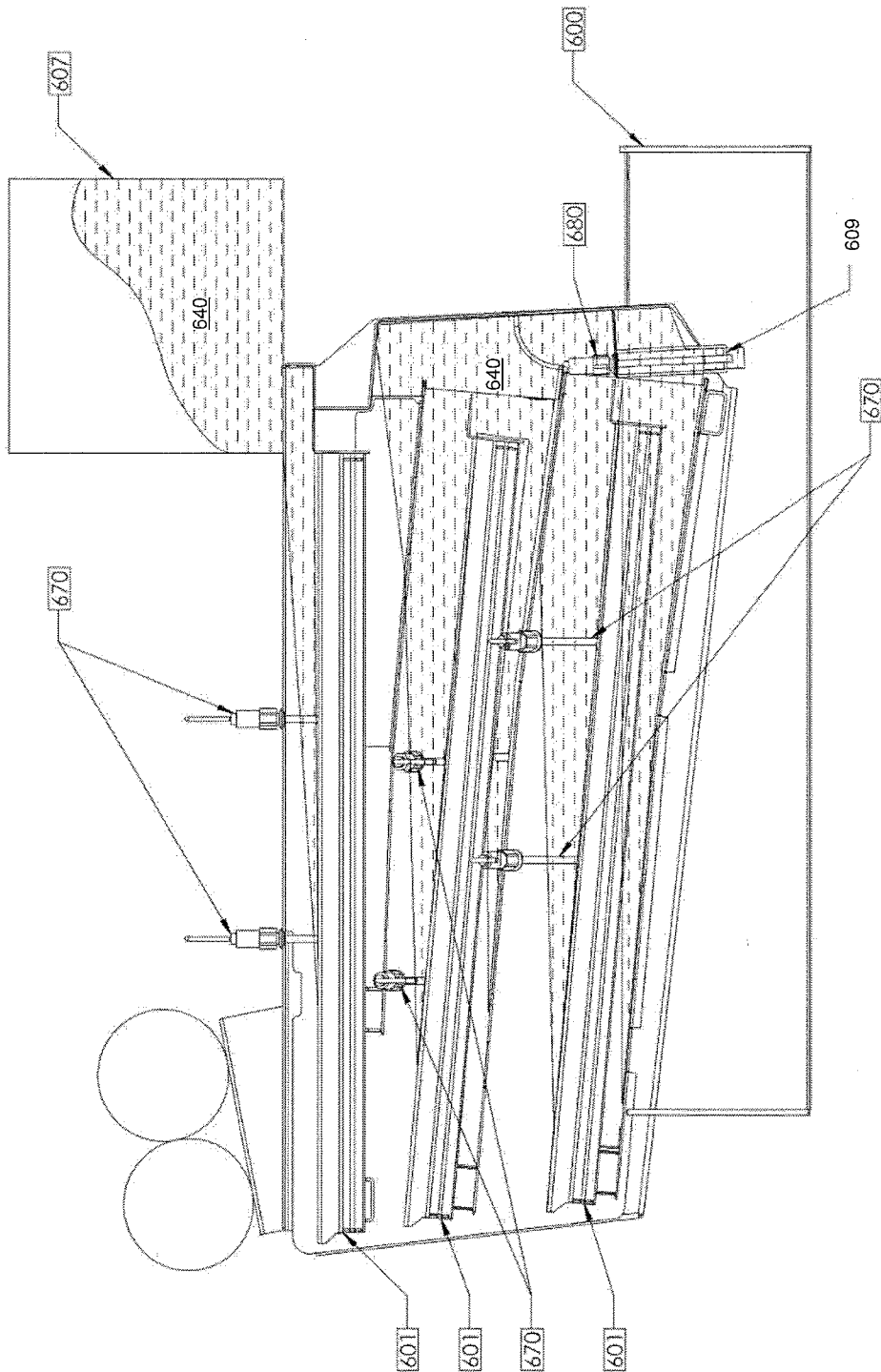
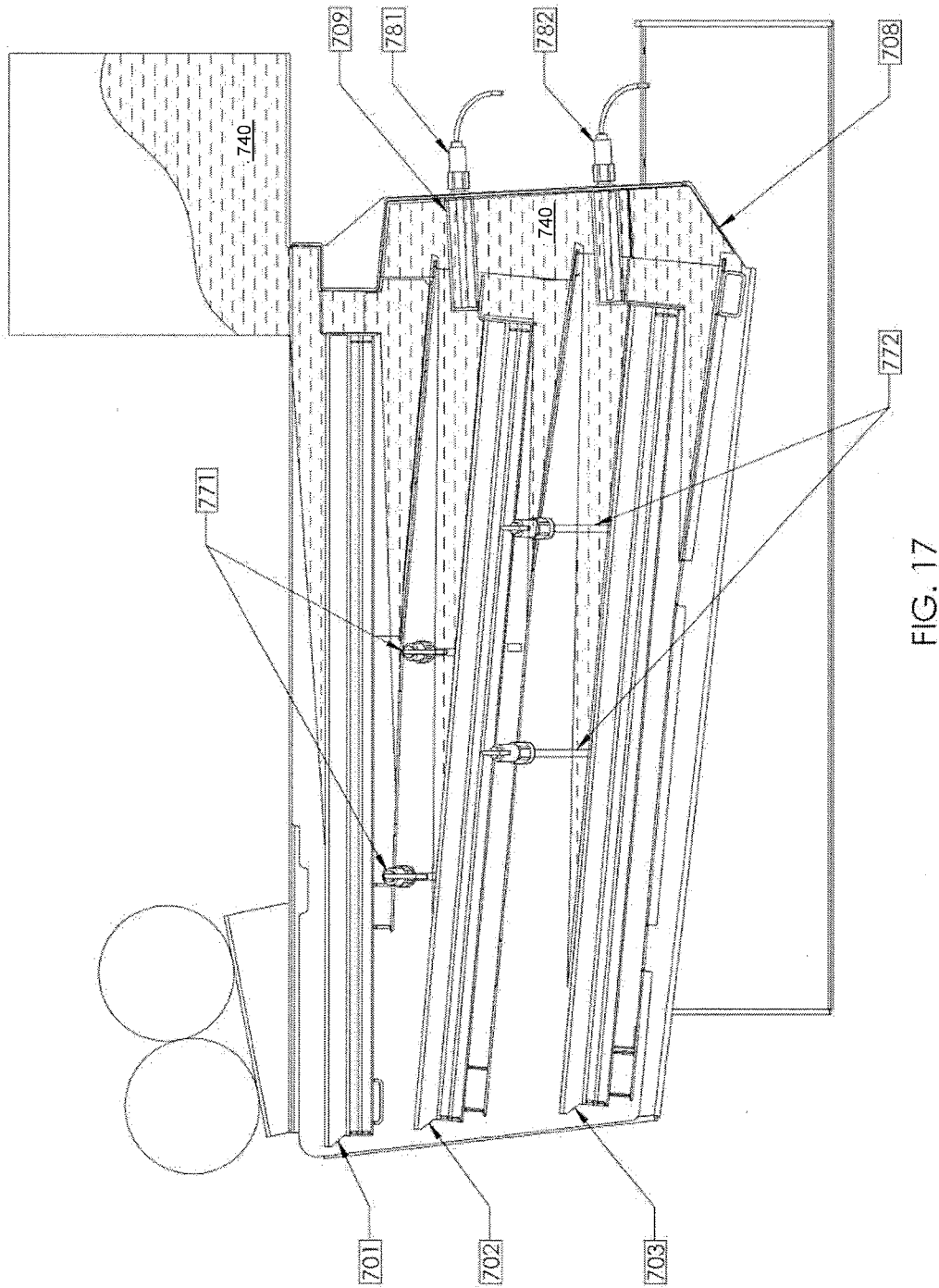


FIG. 16



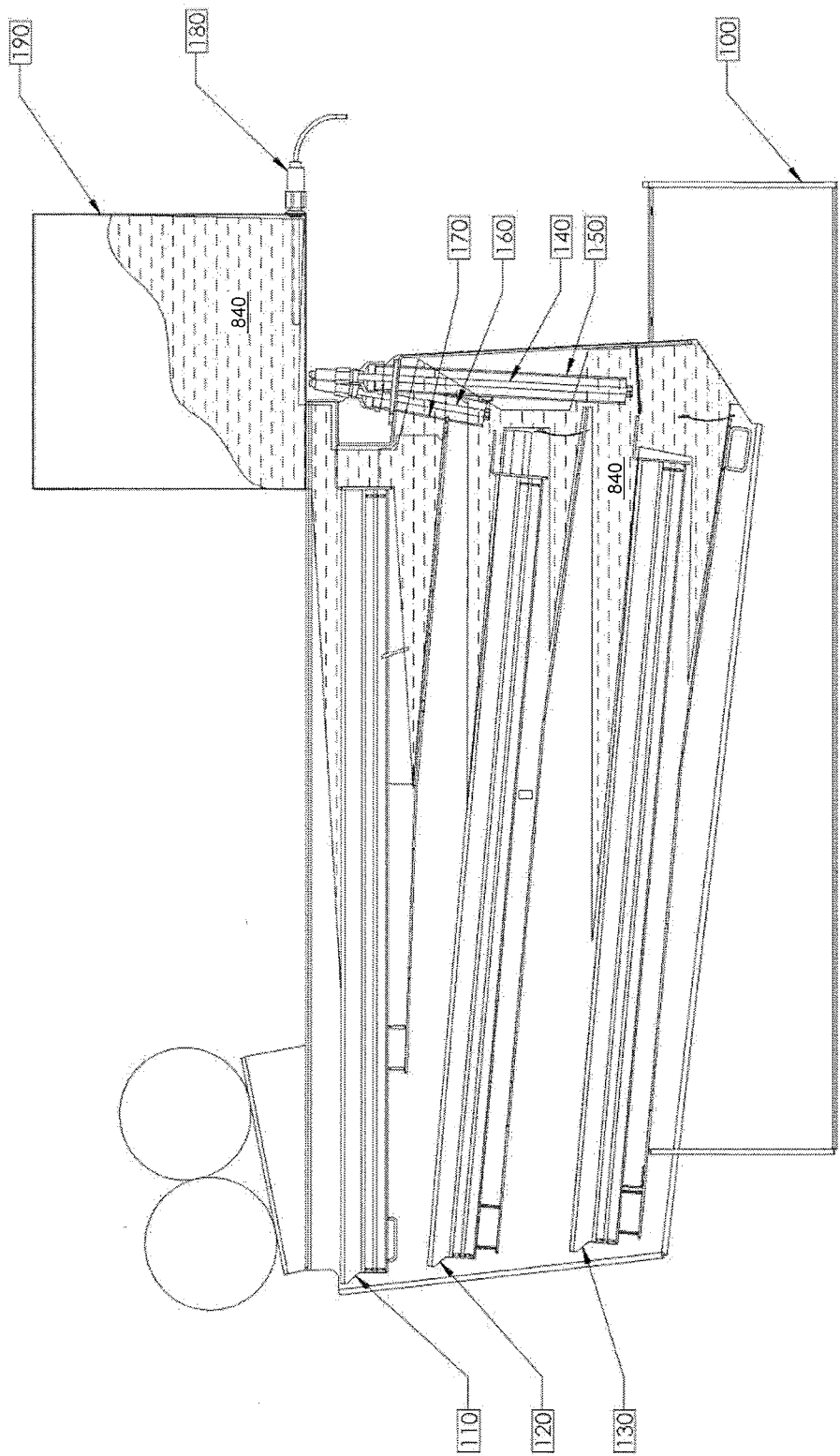


FIG 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/038170**A. CLASSIFICATION OF SUBJECT MATTER****B07B 1/28(2006.01)i, B07B 1/46(2006.01)i, C02F 1/34(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B07B 1/28; B07B 1/49; B07B 1/00; B07B 1/42; B07B 1/46; C02F 1/34

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: vibratating, separator, sensor, probe, screen, reference probe, channel, determining, comparing**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

17 September 2015 (17.09.2015)

Date of mailing of the international search report

18 September 2015 (18.09.2015)

Name and mailing address of the ISA/KR

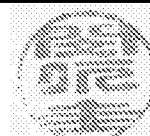
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