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(54) **DOWN HOLE DESANDER**

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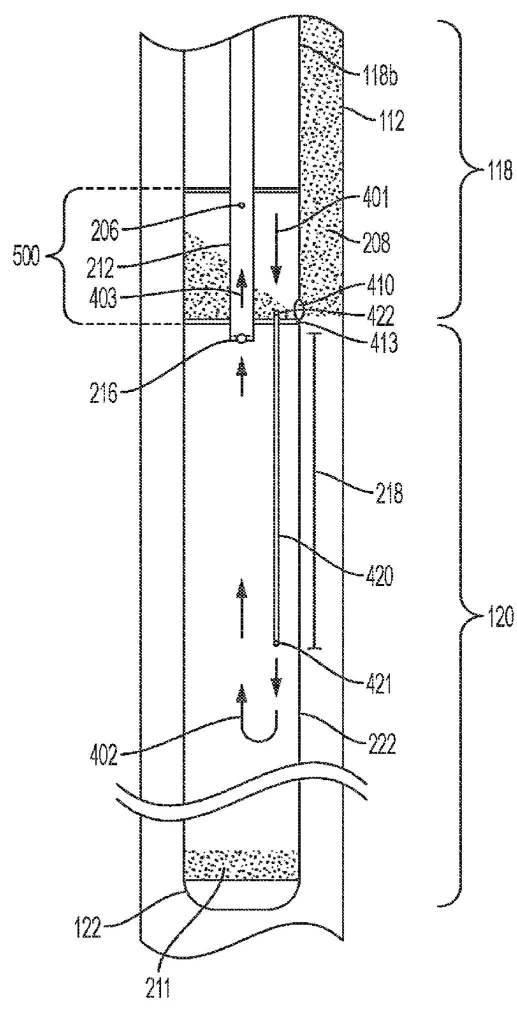
(57) **ABSTRACT**

A downhole solids separator having: a plurality of solids separation modules, a production tube disposed therein, one or more limited entry ports in the production tube, placed in each of the modules, an intake port in the lower half of each module opening into a wellbore annulus, the intake port below the limited entry port of the module, a closed chamber for collecting solids, isolated from the well bore, the closed chamber below modules, a solids conveying conduit from at least one module, opening into the closed chamber, an opening restricted to less than the size of the production tube in the conduit near the bottom of the module, an opening in the production tube in the closed chamber, where the production tube opening and conduit opening are configured to effect a drop fluid velocity into production tube to a level insufficient to carry solids into the production tube.



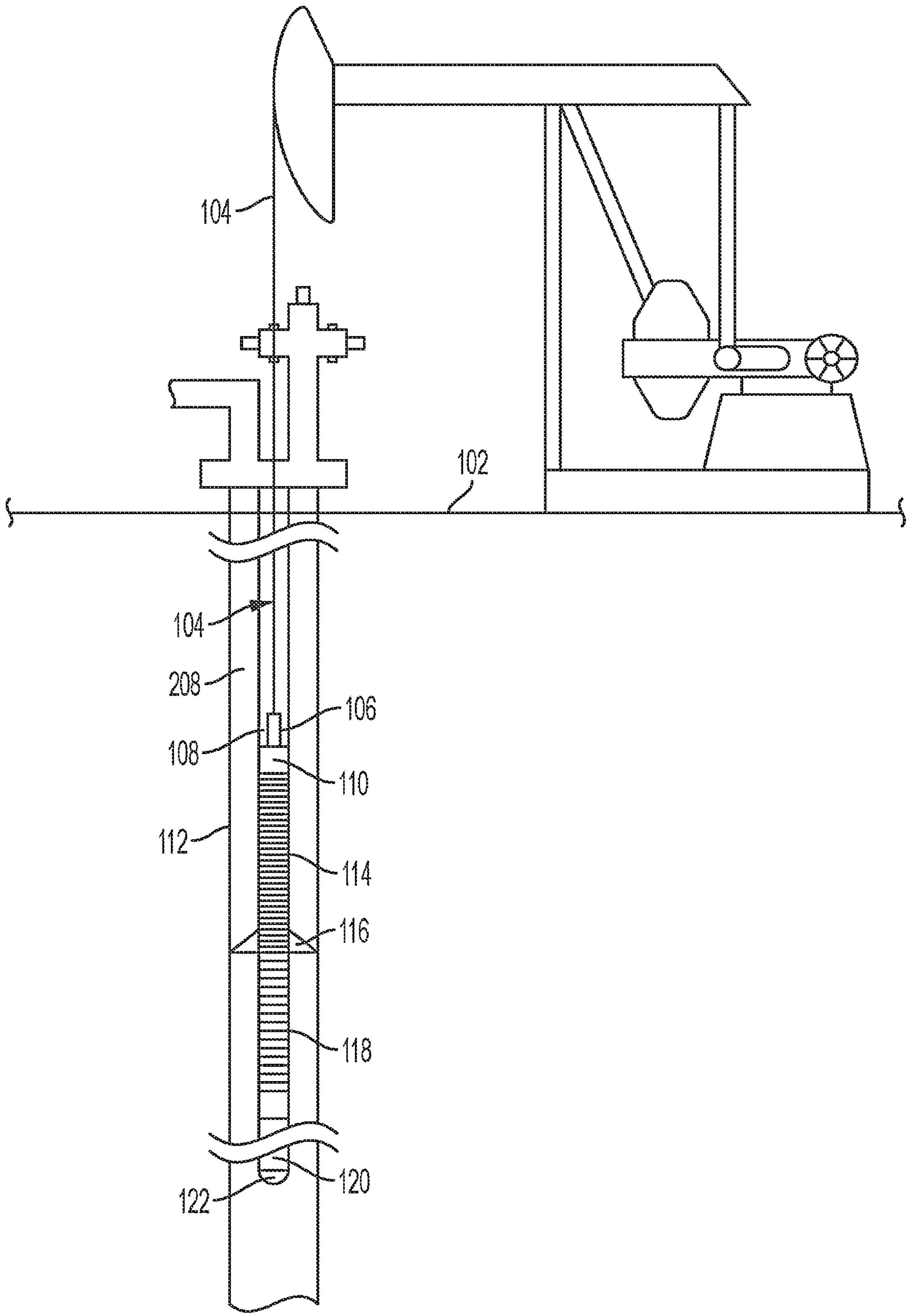
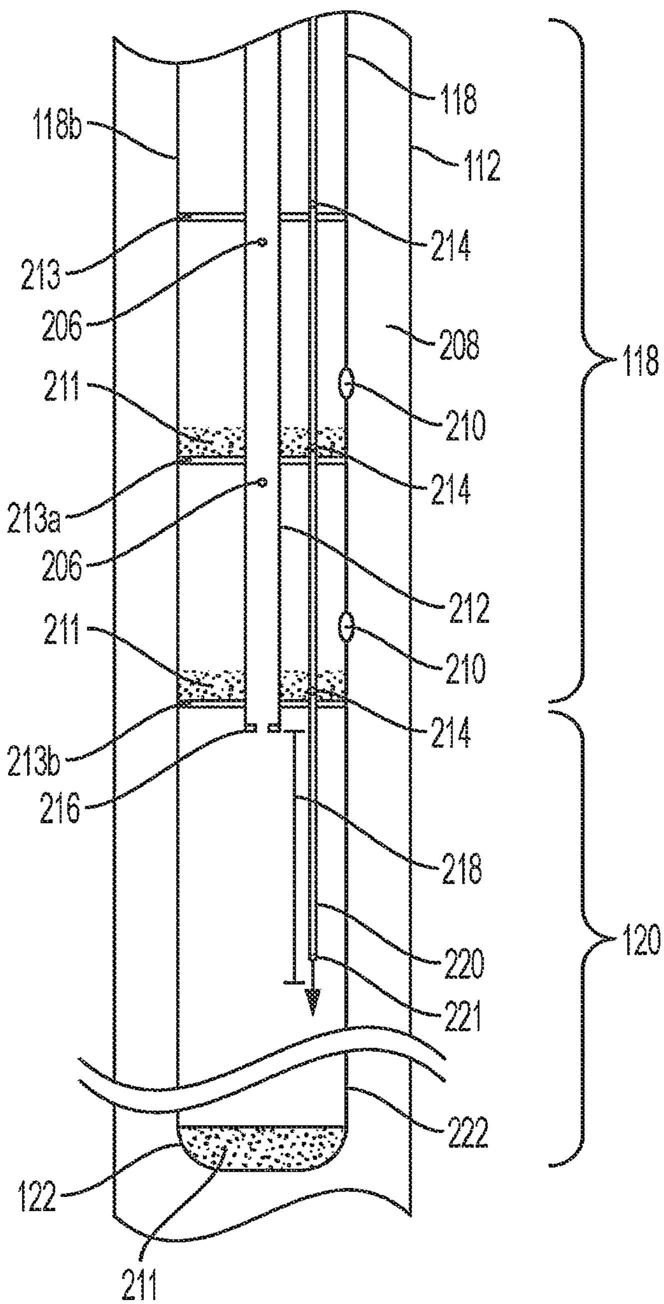


FIG. 1


118b
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112
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208
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216
218
220
120
221
222
122
211

FIG. 2

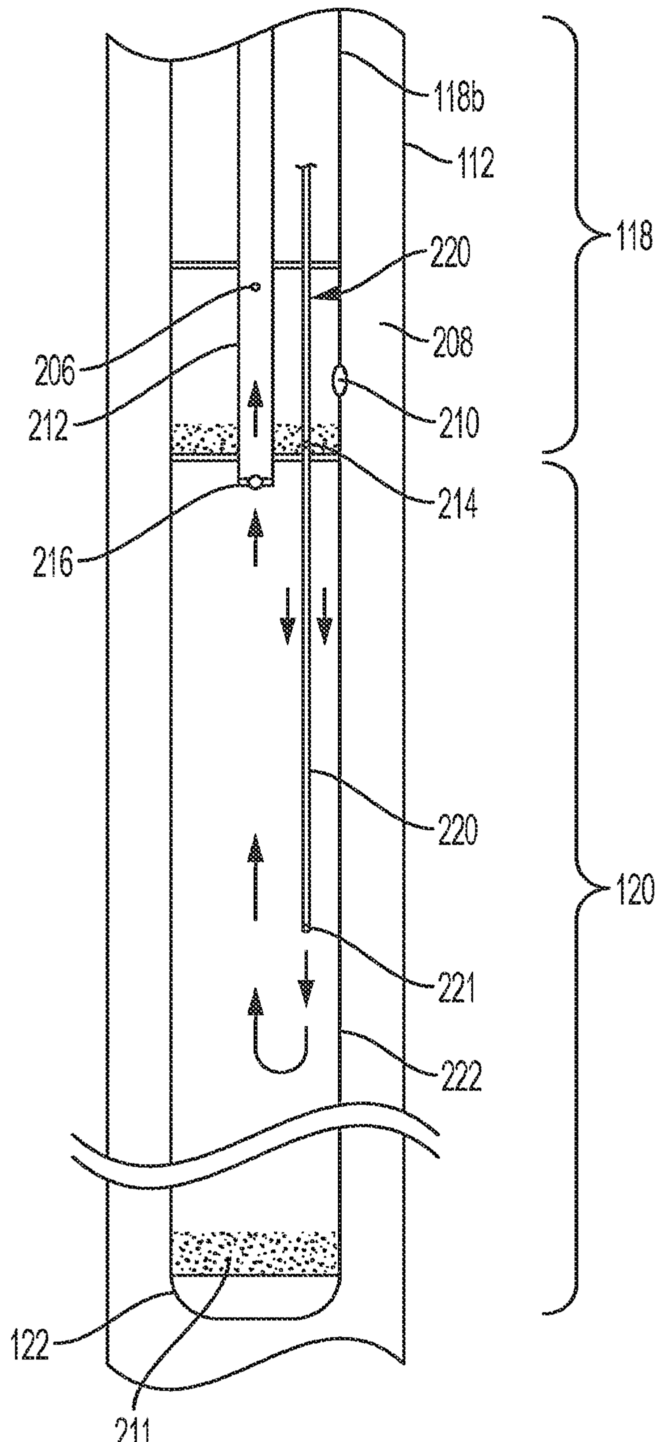
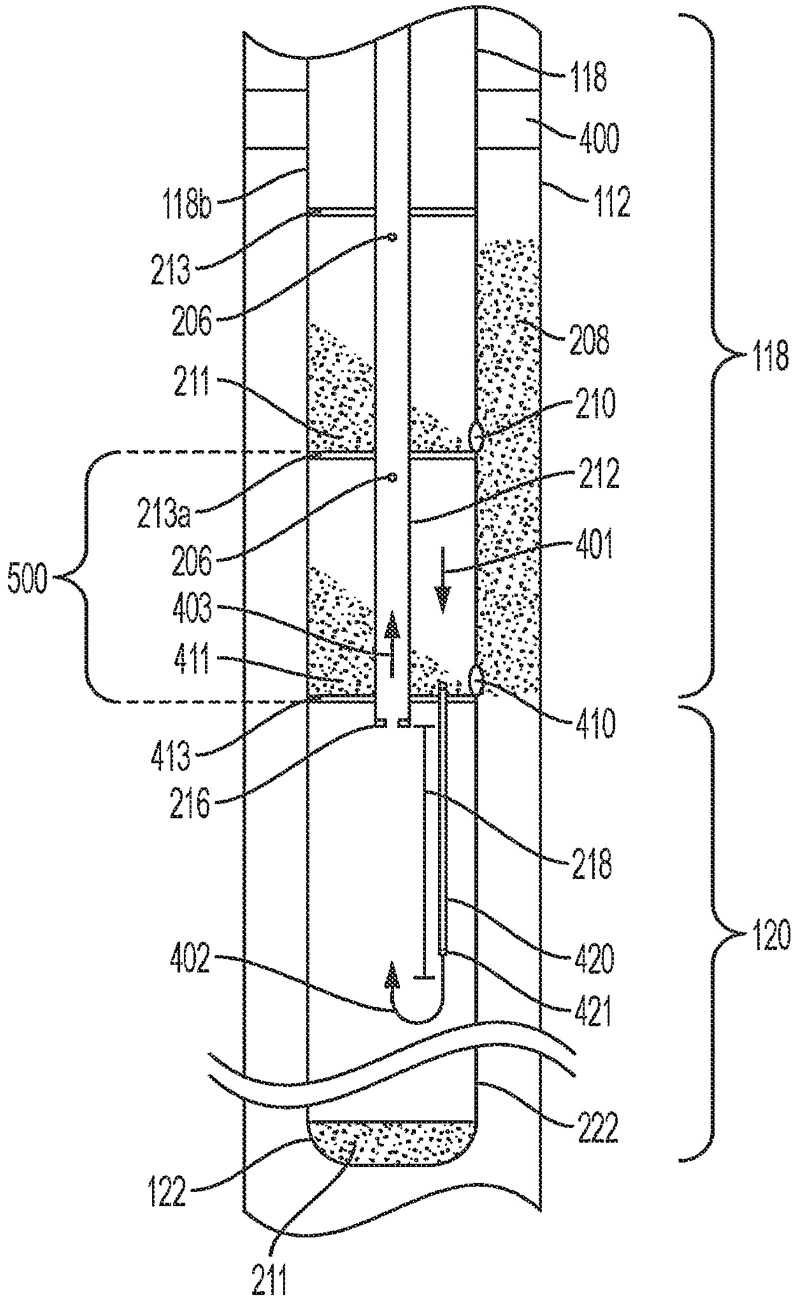


FIG. 3


118
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118b
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210
118
213a
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401
500
403
411
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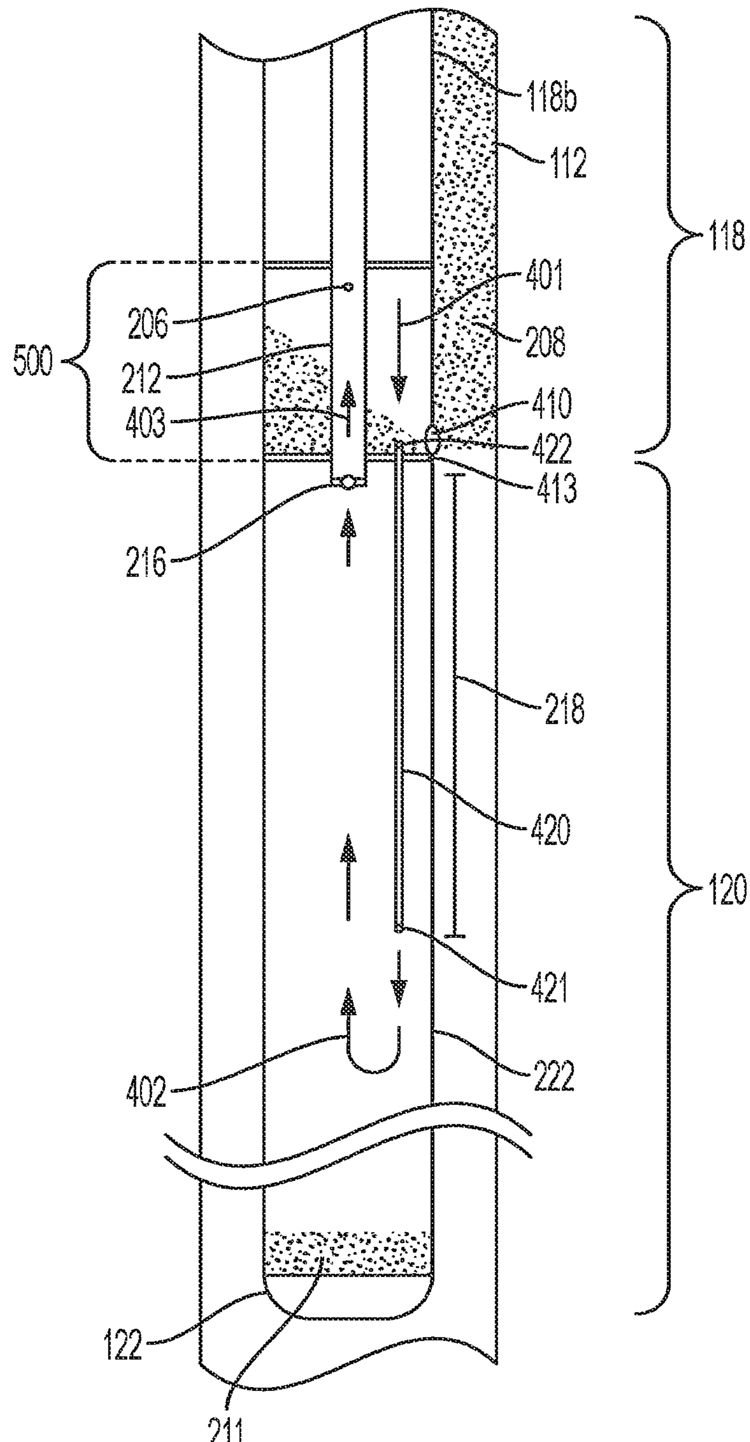
216
218
120
420
402
421
222
122
211

FIG. 4


118b
112
118
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410
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422
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120
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402
222
122
211

FIG. 5

DOWN HOLE DESANDER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 17/750,314, filed May 21, 2022, which claims priority from U.S. Provisional Patent Application Ser. No. 63/208,360, filed Jun. 8, 2021 and U.S. patent application Ser. No. 17/750,314 claims priority from U.S. Provisional Patent Application Ser. No. 63/320,082, filed Mar. 15, 2022, the entire contents of all of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] Disclosed herein are improvements to down-hole solids separation methods, apparatus, and systems, in particular for separating solids from produced fluids in a wellbore, which may be used in conjunction with gas separators.

BACKGROUND OF THE INVENTION

[0003] In the current state of the art, pumping wellbore fluids has the propensity to produce large pockets of gas, over twenty foot (20') columns, and thereby gas-locking a pump, preventing production. Solids, such as sand, may also be produced at the same time, additionally limiting the efficiency of the pump, or worse. There is a strong need to separate gas and solids from production fluids in the wellbore so that pumping efficiency of valuable liquids is not inhibited.

[0004] There is a strong need to separate solids from production fluids in the wellbore so that only liquids are pumped, thus preventing locking of the well and providing more liquid returns from the pump. The inventor has recognized that a separate downhole solids removal apparatus and/or system will greatly improve the operation of down hole gas separators.

BRIEF DESCRIPTION OF DRAWINGS

[0005] FIG. **1** illustrates a schematic frontal diagram of a producing pumping well that has a string of gas separators and the present stack of solids separators of the present invention deployed in the well.

[0006] FIG. **2** illustrates a schematic frontal diagram of a few of the stacked solids separators of the present invention that are attached to the production string that is deployed in a well, operating in parallel, followed by mud joints and bull plug.

[0007] FIG. **3** illustrates a schematic frontal diagram of the present solids separator attached to the production string that is deployed in a well, showing with arrows the flow of solids and fluids in the system.

[0008] FIG. **4** illustrates a schematic frontal diagram of a few of the stacked solids separators of the present invention with modified trash chute and modified intake ports, that are attached to the production string that is deployed in a well, operating in parallel, followed by mud joints and bull plug.

[0009] FIG. **5** illustrates a schematic frontal diagram of the present solids separator with modified trash chute and modified intake ports, attached to the production string that is deployed in a well, showing with arrows the flow of solids and fluids in the system.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Disclosed herein are descriptions of various examples of the invention.

[0011] FIG. **1** illustrates a schematic frontal diagram of a producing pumping well that has a string of gas separators and the present solids separator deployed in the well.

[0012] The tops sides pump jack (not numbered) is placed at or above ground or earth surface **102**, above a cased wellbore **112**. A production tubing string **108** is connected to the topsides at or around surface **102** and runs into the well bore **112**.

[0013] The top sides pump jack holds and controls a pump rod string **104** that holds and controls a pump **106** that is deployed inside production tubing string **108**. In one example, pump rod string **104** is not present, such as on an electric submersible positive cavity pump (ESP).

[0014] Well bore casing **112** and production tubing string **108** forms a well bore annulus **208**.

[0015] Production tubing string **108** holds a production string assembly of several components (**106**, **110**, **114**, **118**, **120**, **122**), as illustrated. In one example, pump **106** is connected to the assembly of components by way of a pump seat nipple **110**.

[0016] The production string assembly (**106**, **110**, **114**, **118**, **120**, **122**) includes: a production tubing string **108** that runs to the surface equipment. Held by a pump rod string **104**, pump **106** is connected to a pump seat nipple **110** which connects to a stack **114** of down hole gas separators. Underneath the stack **114** of downhole gas separators is solids separator **118** of the present invention. Underneath solids separator stack **118** are mud joints **120** and, in one example, terminating in a bull plug **122**, forming the bottom of the production tubing string.

[0017] In one example, the stack **114** of downhole gas separators is a multistage predator-style gas separator system.

[0018] In one example, the stack **118** of solids separators is called a multi-stage sand/solids separator system.

[0019] A packer **116** is disposed in the well bore annulus **208**, for example a well bore CP packer cup. Packer **116** isolates well bore annulus **208** such that gas separator and intake of fluids (and fluids containing solids) is below the packer **116**.

[0020] In one example, the solids-laden fluids are drawn into each of the parallel-operating solids separators of the stack **118** multi-stage sand/solids separator system. These are disposed below the packer **116**. As will be more fully described and shown herein, the solids are eventually deposited into mud joints **120** and bull plug **122**. The sand/solids are pulled into this closed system as all fluids are forced into the stack **118** of sand separators, with sand/solids being pulled down while fluids are being pulled back into the well bore and, in one example, into the gas separators.

[0021] FIG. **2** illustrates a schematic frontal diagram of a few of the stacked solids separators of the present invention that are attached to the production string that is deployed in a well, operating in parallel, followed by mud joints and bull plug.

[0022] Sections **118** and **120** of the production string are deposed inside the wellbore casing **112**, forming wellbore annulus **208**. In one example, multiple solids separators operate independently in parallel to draw in fluids, forming stack **118**. In one example, these solids separators are separated from each other by gaskets **213**. As shown in FIG. **1**, in one example, there is a packer sub **116** that seals off the well bore (well bore annulus **208**) such that fluids are forced into the tool through holes **210** that are placed in the wall of outer pipe **118***b* of the production string of stack **118**. Each of holes **210** provides an entry way into each respective solids separator module. In one example, this enables the solids separators to work on continuous flow. In one example, holes **210** are placed in the lower half of each solids separator module. In one example, holes **210** are restricted openings. In one example, holes **210** are also called thief jets or well entry ports. A dip tube **212** is located inside the stack **118**. Dip tube **212** is a production tube that draws or otherwise receives the final, processed fluids that will be brought to the surface **102** for recovery of energy bearing hydrocarbons (or desired fluids, such as water for a water well). In one example, dip tube **212** passes into mud joints **120** and has an orifice opening at the end of the tube **212**.

[0023] In one example, gaskets **213** isolate each of the solids separator modules of stack **118**. For example, gasket **213***a* forms the top one separator module and gasket **213***b* forms the bottom of that separator module.

[0024] In one example, ports **206** are placed in each of the solids separators to draw fluids in from the separator. In one example, ports **206** are placed in the dip tube **212** at a location in the upper half of the solids separator module. In one example, ports **206** are placed at a location that is at or near the top of the solids separator module. In one example, dip tube **212** goes through gas separators **114** so the fluids entering the dip tube **212** from the solids separators are brought up, above packer **116**, and expelled from the gas separators **114** into the well bore annulus **208** (above the packer **116**) as part of the gas separating process. Thus, in one example, the fluids go right back into the wellbore. Thus, since the packer is above the entry ports **210** of the solids separator tool stack **118**, everything (all the fluids being produced) must go through the solids separators modules, stack **118**.

[0025] In one example, the flow of fluids is continuous flow, all the way through the sand separator modules, tool stack **118**. As the fluids and solids (such as sand) come through the intake port(s) **210**, the solids will accumulate towards the bottom of each solids separator module, and fluids will be pulled from the module through ports **206** and into the dip tube **212**.

[0026] In one example, there is a tube **220** that runs through the solids separator modules and into the mud joints **120**, which we can call a trash chute **220**. In one example, other configurations of tubes and openings can be used to achieve the same function. One end of trash chute **220** terminates into mud joints **120** with an open end **221**. Holes or ports **214** are disposed in trash chute **220** towards the bottom of each solids separator module. As solids **211** accumulate at or near the bottom of each solids separator module, these holes or ports **214** allow the solids **211** to be drawn in to trash chute **220** and expel through bottom end opening **221**, so that the solids **211** dump into the volume enclosed by the mud joints **120** and the solids accumulate into bull plug **122**.

[0027] In one example, a restricted opening **216**, which can be called a fluid entry port or choke back port, is at the bottom opening of dip tube **212**. At the bottom of dip tube **212**, which penetrates into mud joints **120**, the opening **216** is inside the closed system of the mud joints **120**. To draw fluids from the inside enclosure of mud joints **120** causes drawing from opening **221** of trash chute **220**. In one example, the only way to get replenishment is through opening **221**.

[0028] In one example, as the draw from pump **106** can be adjusted, fluids will be pulled from mud joints stack **120** through restricted opening **216** of dip tube **212**. In one example, restricted opening **216** is called a thief jet. Since holes or ports **214** of trash chute **220** are the source of supply for trash chute **220**, solids **211** in each of the solids separator modules of stack **118** will be drawn into trash chute **220** and fall into mud joints **120**, to accumulate at the bottom, for example, in the bottom bull plus **122**.

[0029] In a surprising result, the distance between the bottom of trash chute **220** (the bottom opening **221**) and the restricted opening **216** of dip tube **212** creates what inventor calls a "kill zone". Fluid is demanded from restricted opening **216** of dip tube **212**, based on the demand from pump **106**. Yet, there is only a limited amount of fluid in the mud joints **120**. Thus, the amount of fluid that enters through restricted opening **216** of dip tube **212** is less than the amount of fluid that would be sufficient to create an upward fluid velocity sufficient to levitate the solids out of the mud joints **120** through restricted opening **216** of dip tube **212**. The fluid velocity is "killed". In one example, the port of restricted opening **216** is narrowed to effect this velocity "kill". Arrow **218** illustrates the length of trash chute **220** between restricted opening **216** and bottom opening **221** of trash chute **220** that is engineered with the amount of restriction of opening **216** to effect the "kill zone" in limiting the upward fluid velocity. Thus, the solids (sand, for example) are pulled down out of the bottom of each solids separator module for deposit into the bottom chamber formed by the mud joints **120** and bull plug **122**.

[0030] In one example, gases, liquid, and solids go into the tool through the ports **210**, the sand falls due to natural gravitational force and the gases and fluid rise and flow into the annulus of the tool, to go up and out. With each pump stroke the port will suck out sand through the tube **220** out of the opening **221**, and the solids free gas and fluids go into the wellbore going up.

[0031] In one example, the velocity in the bottom cylinder is not fast enough to suck the solids back up.

[0032] In one example, zone **218** is approximately five feet (5') long and limited entry port **216** is one-quarter inch (¼"). In one example, zone **218** is approximately six feet (6') long. In one example, zone **218** is approximately seven feet (7') long.

[0033] In one example, the solids separation system capitalizes on use of the cross-sectional area. In one example, the tool is much longer, the separator stack **118** ranging in length from thirty feet (30') to ninety feet (90') in length. In one example, the separator stack **118** is approximately thirty feet (30') in length. In one example, the separator stack **118** is approximately sixty feet (60') in length. In one example, the separator stack **118** is approximately ninety feet (90') in length.

[0034] In one example, the system includes a packer placed in the annulus of the wellbore and a dip tube that leads into the wellbore. The system is arranged and configured to create a continuous flow for fluids going through the solids separators from below the packer and then back into the wellbore, above the packer.

[0035] In one example, the dip tube feeds upward into a gas separator or gas separator system. In one example, the gas separator system is as previously disclosed by Gary Marshall in U.S. Pat. No. 10,907,462 and related patent applications. In one example, the size, position and arrangement of the restricted opening **216** of the dip tube, and opening **221** of the trash chute are engineered to cooperate with the gas separator or gas separator system. In one example, the gas separator system is a stack of separator modules. The separator modules draw the fluid to be processed in parallel, adding to the total cross-sectional area of the draw at different vertical heights.

[0036] In one example, the zone of solids **211** in each solids separator module is about three inches (3"). In one example, the orifice **214** of chute **220** is placed within the zone of solids **211**. In one example, this zone of solids is called the "cellar".

[0037] In one example, each solids separator module is twelve inches (12") in height.

[0038] In one example, the restricted opening **216** is placed two inches (2") below the top of the mud joints **120**, for example, two inches (2") from gasket **213***b*.

[0039] In one example, entry ports **210** of the solids separator tool stack **118** are a one-half inch by two inch long slot (½" by 2").

[0040] FIG. **3** illustrates a schematic frontal diagram of the present solids separator attached to the production string that is deployed in a well, showing with arrows the flow of solids and fluids in the system.

[0041] To better illustrate the dynamics of the solids separation system, solids-laden fluid enters the tool below the packer from the wellbore annulus **208**, in through openings **210**. These solids-laden fluids enter into each of the solids separator modules. Fluids are drawn from the solids-laden fluids that are inside the solids separator modules by holes **206** that are in the production dip tube **212**, near the top of the solids separator module. Solids-laden fluids remaining, more concentrated in solids **111**, are drawn into hole **214** in trash chute tube **220**. The solids are drawn down trash chute tube **220**, as indicated by the parallel arrows along trash chute tube **220** inside mud joints **120**. A hole opening at the bottom of trash chute **220** dumps the heavily solid-laden fluid into the mud joints **120**. A limited velocity draw is accomplished by restricted opening **216** into the bottom of the production dip tube **212**, placed near the top of the mud joints **120**. Fluid flows upward and into the dip tube **212**, but at a lower velocity that is insufficient to elevate the solids. In one example, the fluids now in the production dip tube are sent above the packer **116**. In one example, one or more gas separators are above the packer **116** and dump the fluids back into the well bore annulus **208** (above the packer) for gas separation processing by the gas separator or cascade or stack of gas separators. In one example, a series of Marshall-type gas separators running in parallel are used, as more fully described in U.S. Pat. No. 10,907,462 and related patent applications. In one example, the sand separator of the present disclosure is positioned and arranged to work in cooperation with Marshall-type gas separators. In one example, the opening sizes and lengths of the sand separator of the present disclosure is engineered to be adapted to work in cooperation with Marshall-type gas separators.

[0042] As can be appreciated, in the closed system of the solids separators stack **118** and the mud joints **120**, all the fluids are going up. The only downward flow is in the trash chute tube **220** coming from the bottom of each solids separator module, from the trash chute intake ports **214**. In the closed loop solids retrieval system, the velocity is slowed down for the sand/solids to fall to the bottom because of gravity, and only the solids-free fluid will travel back into the wellbore at the top of the sand separator **118**, above the packer sub **116**.

[0043] In one example, the solids separator modules are stacked in multiples for ease in deployment in the field. In one example, the solids separator modules form a stack in multiples. In one example, the solids separator stack includes ten (10) solids separator modules. In one example, the solids separator stack includes twenty (20) solids separator modules. In one example, the solids separator stack includes thirty (30) solids separator modules. In one example, the solids separator stack includes fifty (50) solids separator modules.

[0044] In one example, wellbore intake holes **210** of the solids separator tool stack **118** are thief jets. In one example, wellbore intake holes **210** of the solids separator tool stack **118** are thief jets ranging in opening size of from 1⁄16" to V4", these are in the top of each sand separator module. In one example, wellbore intake holes **210** of the solids separator tool stack **118** are thief jets, placed in multiples.

[0045] In a particular, preferred example of the solids separation system: the dip tube is ⅝";

- [0046] the trash chute is ½", while the wellbore casing is 7";
- [0047] the mudjoints are 3 ½" outside diameter with an inside diameter of 3";
- [0048] with a ⅝" dip tube placed inside and a ½" trash chute placed inside the production string;
- [0049] with the mud joints stack, including the bull plug, being ten feet 10' long;
- [0050] with the restricted entry port at the end of the dip tube and placed in the mud joints stack being ¼" opening with a fluid velocity kill zone being five feet length (approximate distance from restricted entry port at the end of the dip tube to the bottom opening of the trash chute); and
- [0051] with the solids separator modules being twelve inches (12") in length each.

[0052] In one example, the dip tube is ⅝".

[0053] In one example, the trash chute is ½".

[0054] In one example, the wellbore casing is 7".

[0055] In one example, the mud joints are 3 ½", thus an outside diameter of 3 ½" and in inside diameter of 3" with a ⅝" dip tube placed inside and a ½" trash chute placed inside.

[0056] In one example, the mud joints stack **120**, including the bull plug **122**, is ten feet 10' long.

[0057] In one example, the restricted entry port **216** is ¼" with a fluid velocity kill zone **218** of five feet (5').

[0058] In one example, the solids separator module is twelve inches (12").

[0059] In one example, herein disclosed is a downhole solids separator, the separator including:

- [0060] a plurality of solids separation modules (**118**),
- [0061] a production tube (**212**) disposed in the solids separation modules (**118**),
- [0062] one or more limited entry ports (**206**) in the production tube (**212**), the limited entry port placed in each of the plurality of solids separation modules (**118**),

[0063] an intake port (**210**) disposed in the lower half of each solids separation module opening into a wellbore annulus (**208**), the intake port (**210**) disposed below the location of the limited entry port (**206**) of the corresponding module,

[0064] a closed chamber (**120**) for collecting solids, isolated from the well bore, the closed chamber disposed below the lower most solids separation cylinder,

[0065] a conduit (**220**) positioned and arranged for the conveying of solid materials, the conduit disposed through each solids separation module, the conduit having a lower end disposed in the closed chamber (**120**),

[0066] an opening (**214**) in the conduit in each of the solids separation modules, the opening disposed near the bottom of the corresponding solids separation module, a delivery opening (**221**) disposed at the lower end of the conduit (**220**), opening into the closed chamber (**120**),

[0067] an opening (**216**) in the production tube (**212**), the opening (**216**) disposed in the closed chamber (**120**),

[0068] wherein the opening (**216**) in the production tube (**212**) is restricted to less than the size of the production tube, and

[0069] wherein opening (**216**) and delivery opening (**221**) are sized, positioned and arranged to effect a drop fluid velocity into production tube (**212**) to a level insufficient to carry solids into the production tube (**212**).

[0070] In a further example, additionally, entry ports (**210**) are disposed below a packer (**116**) that closes the wellbore annulus (**208**) and production tube (**212**) delivers the fluids drawn from opening (**216**) to a location above packer (**116**).

[0071] In a further example, the fluids drawn from opening (**216**) are expelled into the wellbore annulus (**208**) at a location above packer (**116**).

[0072] FIG. **4** illustrates a schematic frontal diagram of a few of the stacked solids separators of the present invention with modified trash chute and modified intake ports, that are attached to the production string that is deployed in a well, operating in parallel, followed by mud joints and bull plug. FIG. **5** illustrates a schematic frontal diagram of the present solids separator with modified trash chute and modified intake ports, attached to the production string that is deployed in a well, showing with arrows the flow of solids and fluids in the system.

[0073] In one example, the trash chute is absent in the solids separator modules, except the bottommost module **500**. In bottommost module **500**, one end (**422**, FIG. **5**) of the trash chute tube **420** opens near the bottom of module **500** and progresses downward into mud joints stack **120**. The length of the trash chute tube **420** in the mud joints stack **120** defines or is otherwise associated with the kill zone as indicated by bar **218**. In one example, intake port **410** is located toward or at the bottom of bottommost separator module **500**. In one example, intake ports **210** in the other solids separator modules of stack **118** are also disposed toward or at the bottom of each solids separator module.

[0074] In this configuration, intake ports **210** and **410** serve to also dump solids back into wellbore annulus **208**. This is illustrated by the triangular shape of accumulated sands or solids **211** and **411** in each of the solids separator modules. The inventor has recognized that the fluid column in the annular region **208** around the tool in the wellbore can only hold a certain amount of sand (solids) and that higher concentrations are recognized in the lower portion of the demand fluid column. Hence, in this example, a modified positioning, size, and arrangement of the intake ports **210** and **410** as well as placement of the trash chute **420** in the bottommost solids separator module **500**, eliminating the trash chute in upper solids separator modules.

[0075] Thus, solids-laden fluid flow in bottommost solids separator **500** is downward into trash chute **420** at top opening **422**, as indicated by flow arrow **401**. As indicated by flow arrow **402**, the fluids exit the trash chute **420** at bottom opening **421** into mud joints **120** and proceed to flow upward toward restricted orifice **216** that opens into the bottom of production dip tube **212**. As indicated by flow arrow **403**, fluids then flow upward in the production did tube **212** as drawn by the pump. Each solids separator module has an orifice **206** in the production dip tube **212**, near the top of each module. Each office **206** in the solids separator modules enables solids-depleted fluids to be drawn from each solids separator module and into the production dip tube **212**.

[0076] In one example, bottommost solids separator module **500** (the bottom cylinder) is one foot in height. In one example, restricted orifice **216** that opens into the bottom of production dip tube **212** is a ¼ inch opening. In one example, the fluid velocity kill zone **218**, representing the effective length of trash chute **420**, is five feet.

[0077] In one example, gaskets **213***a* and **413** of bottommost solids separator module **500** (the bottom cylinder) is a sandwiched construction of a metal plate, gasket, gasket, and metal plate. Thus, two gaskets are sandwiched between a top metal plate and a bottom metal plate, creating barrier or what is illustrated as gasket **413**.

[0078] In one example, a perforated cup sub is used for packer **116**. In one example, a non-perforated cup sub is used for packer **116**. In one example, fluids drawn through production dip tube **212** go directly to a pump. In one example, fluids drawn through production dip tube **212** go through gas separators. In one example, the gas separators used are as previously disclosed by Gary Marshall in U.S. Pat. No. 10,907,462 and related patent applications and the solids separators are engineered to operate cooperatively with these type of separators.

[0079] In one example, the sizes of the orifices **206** in the production dip tube **212** are varied from solids separator module to module. In one example, the orifices **206** are made larger going down to lower solids separator modules in the stack **118**.

Conclusion

[0080] Although the present invention is described herein with reference to a specific preferred embodiment(s), many modifications and variations therein will readily occur to those with ordinary skill in the art. Accordingly, all such variations and modifications are included within the intended scope of the present invention as defined by the reference numerals used.

[0081] From the description contained herein, the features of any of the examples, especially as set forth in the claims, can be combined with each other in any meaningful manner to form further examples and/or embodiments.

[0082] The foregoing description is presented for purposes of illustration and description, and is not intended to limit the invention to the forms disclosed herein. Consequently, variations and modifications commensurate with the above teachings and the teaching of the relevant art are within the spirit of the invention. Such variations will readily suggest themselves to those skilled in the relevant structural or mechanical art. Further, the embodiments described are also intended to enable others skilled in the art to utilize the invention and such or other embodiments and with various modifications required by the particular applications or uses of the invention.

1. (canceled)

2. A down-hole solids-separation apparatus, configured for installation in a production string within a wellbore, comprising:

an outer tubular body defining a separator chamber;

an upper annular gasket and a lower annular gasket axially spaced on the outer tubular body to isolate the separator chamber from adjacent portions of the production string;

at least one well-entry port passing through the outer tubular body at a location below the upper gasket and above the lower gasket, the port being sized to admit well fluids laden with particulate solids into the separator chamber;

a dip tube extending axially through the separator chamber and beyond the lower gasket into a collection region, the dip tube including a restricted fluid-entry port positioned within the collection region; and

wherein, during operation, solids carried by fluids entering through the well-entry port settle by gravity below the restricted fluid-entry port while solids-depleted fluid is drawn through the restricted fluid-entry port into the dip tube for production to surface, thereby reducing re-entrainment of settled solids.

3. The apparatus of claim **2**, wherein the restricted port is smaller in flow area than an internal bore of the dip tube.

4. The apparatus of claim **2**, further comprising a solids-conveying conduit having an intake opening located adjacent a bottom portion of the separator chamber.

5. The apparatus of claim **3**, further comprising a delivery opening terminating in the collection region below the lower gasket

6. The Apparatus of claim **5**, wherein the conduit is configured to transfer settled solids from the separator chamber to the collection region for permanent deposition.

7. The apparatus of claim **2**, wherein a second well-entry port is formed through the outer tubular body at a vertical position intersecting a line that defines a kill-zone length, thereby enabling additional fluid intake into the collection region below the separator chamber.

8. The apparatus of claim **2**, wherein a plurality of restricted fluid-entry ports are provided in the dip tube and a flow area of the restricted fluid-entry ports increases progressively in a downward direction along the dip tube to balance flow across multiple separator chambers.

9. The apparatus of claim **2**, wherein an axial distance between the restricted fluid-entry port and a delivery opening of a solids-conveying conduit defines a kill-zone having a length of at least five feet (1.5 m) so that an upward velocity of fluid entering the dip tube is insufficient to lift solids from the collection region.

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