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(54) SOLID PARTICLE SEPARATION IN OIL AND/OR GAS PRODUCTION

(57) An apparatus for separating solid particles from a hydrocarbon-containing fluid produced from an oil and/or gas production facility, the apparatus comprising a primary production conduit having an upstream portion and a downstream portion, at least one valve connected to the upstream portion, the valve having a first outlet in fluid communication with the primary production conduit, a second outlet in fluid communication with a solid particle separation unit and an inlet connectable to an oil and/or gas production well, wherein the first and second outlets of the valve are selectively connectable to the upstream portion or the solid particle separation unit, and the valve being actuatable to select between the respective first and second outlets, the solid particle separation unit comprising at least one solid separator and having a first output for solids and a second output for fluids, the second output being in fluid communication with an input of a fluid separator having a liquid output and a gas output, the liquid output being in fluid communication with the downstream portion by a return conduit, a controller for controlling liquid flow from the fluid separator to the downstream portion along the return conduit and a pressure boosting pump in the return conduit for pressurising liquid in the return conduit and pumping the pressurised liquid in the return conduit in a direction from the fluid separator to the downstream portion, the controller being adapted to control any one or more, in any combination, of any of an output pressure of the pump; a flow rate of the pump; and an on/off function of the pump. There is also disclosed a method of separating solid particles from such a hydrocarbon-containing fluid. There is also disclosed a system and method of removing solids from an oil well by fluidising the solids.

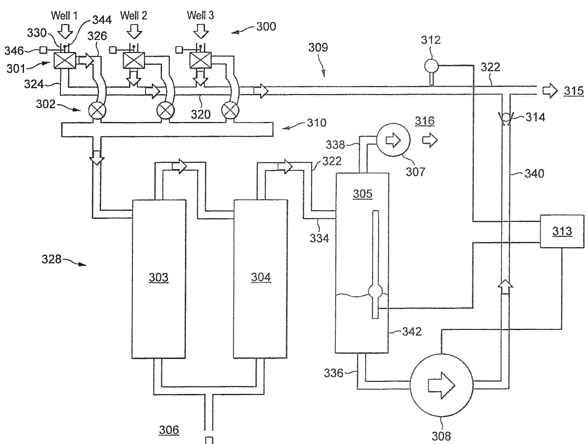

FIG. 4

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Description

[0001] The present invention relates to an apparatus for, and a method of, separating solid particles from a hydrocarbon-containing fluid produced from an oil and/or gas production facility. The present invention also relates to a solids removal system in an oil well and to a method of removing solids from an oil well. In particular, this invention relates to an apparatus and method for the removal of solids from a well in order to increase its production and allowing the comingling of its production with the production of other wells on the same oil and/or gas production platform. These apparatus and method also allow for the solid separation and washing of the removed solids.

[0002] Many offshore oil and gas fields are developed and produced using a multi-well platform. In general a template is placed on the seabed, which comprises slots and a well is drilled through each slot. It is not uncomment to have 10 to 20 wells drilled from a single template. Each well will be drilled to hit a particular reservoir target or targets. The trajectory of the wells can be very different but care is taken to make sure that the wells do not collided with each other.

[0003] The production performance for the individual wells can be very different as each well targets a different geological horizons or reservoirs or different parts of the same reservoir. As production from the field continues over many years, the production from some wells may drop more rapidly than from others as the target reservoirs of each depletes at different rates. The production from all the wells on the template will be collected and processed with a single platform. Therefore this platform needs to deal with differing production pressures and flowrates over the life of the wells it is handling. In some cases, the production from one or more wells is extremely low having a much lower production pressure than other wells on the same template. A common cause of this is the build-up of solids in these low producing wells. Often after many years of productions and as the reservoir becomes more depleted, the formation pressure is reduced and as a result the production flow rate is likewise reduced. In addition, sand production from such depleted reservoir can increase as the stress state in the reservoir changes because of changes in the reservoir pressure. With the flow rate also decreasing the produced sand is not fully removed from the well and so collects and chokes the production even further. In some cases when the pressure in the reservoir reduces water is injected into offset wells to increase the reservoir pressure and 'sweep' the oil towards the production well(s). It is not uncommon for this injected water to also increase the sand production in the producing well. Methods exist to remove this sand from the well(s) but in many cases the sand is collected and shipped onshore for processing. Also, even after removal of the sand the well(s) flow rate and pressure can be a lot less than other wells producing on the same platform. As a result, the production from this well(s) cannot be handle in the same way and is generally collected in tanks and is periodically dealt with in a 'batch' mode, e.g., shipped on shore. This requires large tanks on the platform that take a lot of space (or have a large footprint), which in turn increases the platform size and cost.

[0004] The present inventors have worked to establish technical solutions to the above restrictions associated with technology presently used in the industry or disclosed in the prior art.

[0005] The present invention accordingly provides an apparatus for separating solid particles from a hydrocarbon-containing fluid produced from an oil and/or gas production facility, the apparatus comprising a primary production conduit having an upstream portion and a downstream portion, at least one valve connected to the upstream portion, the valve having a first outlet in fluid communication with the primary production conduit, a second outlet in fluid communication with a solid particle separation unit and an inlet connectable to an oil and/or gas production well, wherein the first and second outlets of the valve are selectively connectable to the upstream portion or the solid particle separation unit, and the valve being actuatable to select between the respective first and second outlets, the solid particle separation unit comprising at least one solid separator and having a first output for solids and a second output for fluids, the second output being in fluid communication with an input of a fluid separator having a liquid output and a gas output, the liquid output being in fluid communication with the downstream portion by a return conduit, a controller for controlling liquid flow from the fluid separator to the downstream portion along the return conduit and a pressure boosting pump in the return conduit for pressurising liquid in the return conduit and pumping the pressurised liquid in the return conduit in a direction from the fluid separator to the downstream portion, the controller being adapted to control any one or more, in any combination, of any of an output pressure of the pump; a flow rate of the pump; and an on/off function of the pump.

[0006] Preferably, wherein the controller is adapted to control the output pressure of the pump so as to be above the liquid pressure in the primary production conduit. Typically, the controller is adapted to control the output pressure of the pump so as to be above the liquid pressure in the primary production conduit by a pre-set minimum pressure difference. Optionally, the apparatus further comprises a pressure sensor for measuring liquid pressure in the primary production conduit, the pressure sensor being connected to the controller to output a pressure signal to the controller to control the output pressure of the pump.

[0007] Preferably, the apparatus further comprises a reservoir sensor for measuring a liquid amount in a reservoir of the fluid separator, and the controller is adapted to output a control signal to control liquid flow from the fluid separator to the downstream portion along the return conduit when the liquid amount is above a pre-set threshold. Typically, the reservoir sensor is a liquid level sensor. Preferably, the control signal is adapted to cause or permit liquid flow from the fluid separator to the downstream portion when the liquid level in the reservoir of the fluid separator is above a pre-set threshold level. Preferably, wherein the control signal is adapted to maintain the liquid level in the reservoir of the fluid separator above a pre-set minimum threshold level and/or below a pre-set maximum threshold level.

[0008] In some embodiments, the pump is configured to restrict liquid flow from the downstream portion to the fluid separator along the return conduit.

[0009] In other embodiments, the apparatus further comprises a non-return valve in the return conduit between the pump and the primary production conduit to restrict liquid flow from the downstream portion to the fluid separator along the return conduit. Typically, the non-return valve is self-regulating to open to provide flow therethrough in a forward direction at a pre-set pressure difference across the non-return valve. Alternatively, the controller may be adapted to control the non-return valve to open to provide flow therethrough in a forward direction at a pre-set pressure in the return conduit upstream of the non-return valve or at a pre-set pressure difference across the non-return valve. Optionally, the controller is adapted to control the non-return valve to open to provide flow therethrough in a forward direction when the pre-set pressure in the return conduit upstream of the non-return valve is above the liquid pressure in the primary production conduit by a pre-set minimum pressure difference.

[0010] Preferably, the apparatus further comprises a gas compressor coupled to the gas output of the fluid separator for providing a supply of compressed gas from the fluid separator. Typically, an outlet of the gas compressor is coupled to a gas production conduit of the gas production facility. Preferably, the controller is adapted to control the output pressure of the gas compressor so as to be above the gas pressure in the gas production conduit. Optionally, the controller is adapted to control the output pressure of the gas compressor so as to be above the gas pressure in the gas production conduit by a pre-set minimum pressure difference.

[0011] The apparatus may further comprise a pressure sensor for detecting fluid pressure in the valve inlet, and a valve control for switching the inlet into fluid communication with the second outlet when the detected fluid pressure is below a pre-set pressure threshold or when a pressure difference between the detected pressure and pressure in the primary production conduit is above a pre-set minimum pressure difference.

[0012] Optionally, the at least one valve comprises a plurality of three-way valves connected to the upstream portion, each three-way valve having a first outlet in fluid communication with the primary production conduit, a second outlet in fluid communication with the solid particle separation unit and an inlet connectable to an oil and/or gas production well, wherein the first and second outlets of each three-way valve are selectively connectable to the upstream end or the solid particle separation unit, and the plurality of three-way valves are individually actuatable to select between the respective first and second outlets.

[0013] Typically, the solid particle separation unit has a common manifold to which each second outlet is connected either directly or by an intermediate conduit and/or valve connecter system.

[0014] The present invention further provides a method of separating solid particles from a hydrocarbon-containing fluid produced from an oil and/or gas production facility, the method comprising the steps of:

(i) providing a hydrocarbon-containing fluid produced from an oil and/or gas production well to an upstream portion of a primary production conduit;
(ii) selectively diverting the fluid away from the primary production conduit to a solid particle separation unit if the fluid has a solid particle content above a particular threshold and/or a pressure below a particular threshold;
(iii) in the solid particle separation unit separating the hydrocarbon-containing fluid to provide a solids output and a fluids output;
(iv) separating the fluids output into a liquid output and a gas output in a fluid separator;
(v) pressurising the liquid output; and
(vi) pumping, by a pump, the pressurised liquid output to a downstream portion of the primary production conduit along a return conduit.

[0015] Typically, the pressurising of step (v) and the pumping of step (vi) are carried out by a pressure booster pump. Optionally, the pressurising of step (v) and the pumping of step (vi) are carried out by controlling any one or more, in any combination, of any of an output pressure of the pump; a flow rate of the pump; and an on/off function of the pump.

[0016] Optionally, the pressurising of step (v) and the pumping of step (vi) are carried out by controlling the pressure of the pressurised liquid so as to be above the liquid pressure in the primary production conduit. Typically, the pressure of the pressurised liquid is controlled so as to be above the liquid pressure in the primary production conduit by a pre-set minimum pressure difference. Preferably, the method further comprises measuring liquid pressure in the primary production conduit to provide a pressure signal to which is used to control the pressure of the pressurised liquid.

[0017] Preferably, the method further comprises measuring a liquid amount in a reservoir of the fluid separator, and controlling liquid flow from the fluid separator to the downstream portion along the return conduit when the liquid amount is above a pre-set threshold. Preferably, the reservoir sensor is a liquid level sensor. Typically, the controlling causes or permits liquid flow from the fluid separator to the downstream portion when the liquid level in the reservoir of the fluid separator is above a pre-set threshold level. Preferably, the liquid level in the reservoir of the fluid separator is maintained above a pre-set minimum threshold level and/or below a pre-set maximum threshold level.

[0018] In some embodiments, the pump is configured to restrict liquid flow from the downstream portion to the fluid separator along the return conduit.

[0019] In other embodiments, a non-return valve in provided in the return conduit between the pump and the primary production conduit to restrict liquid flow from the downstream portion to the fluid separator along the return conduit. Optionally, the non-return valve is self-regulating to open to provide flow therethrough in a forward direction at a pre-set pressure difference across the non-return valve. Alternatively, the method further comprises controlling the non-return valve to open to provide flow therethrough in a forward direction at a pre-set pressure in the return conduit upstream of the non-return valve or at a pre-set pressure difference across the non-return valve. Typically, the non-return valve is controlled to open to provide flow therethrough in a forward direction when the pre-set pressure in the return conduit upstream of the non-return valve is above the liquid pressure in the primary production conduit by a pre-set minimum pressure difference.

[0020] Preferably, the method further comprises detecting fluid pressure in the hydrocarbon-containing fluid, and switching the hydrocarbon-containing fluid into fluid communication with the solid particle separation unit when the detected fluid pressure is below a pre-set pressure threshold or when a pressure difference between the detected pressure and pressure in the primary production conduit is above a pre-set minimum pressure difference.

[0021] Typically, in step (ii) the diverting is carried out by a three-way valve connected to the upstream portion, the three-way valve having a first outlet in fluid communication with the primary production conduit, a second outlet in fluid communication with the solid particle separation unit and an inlet connected to the oil and/or gas production well, wherein the first and second outlets of the three-way valve are selectively connectable to the upstream portion or the solid particle separation unit.

[0022] Optionally, the oil and/or gas production facility comprises a plurality of wells and a hydrocarbon-containing fluid produced from a plurality of oil and/or gas production wells is provided simultaneously to the upstream portion of the primary production conduit; and in step (ii) the diverting is carried out by a plurality of the three-way valves connected to the upstream portion, each three-way valve having the respective inlet connected to a respective oil and/or gas production well, and the plurality of three-way valves being individually actuatable to connect the respective well to the primary production conduit or to the solid particle separation unit. Preferably, the solid particle separation unit has a common manifold to which a respective second outlet of each three-way valve is connected either directly or by an intermediate conduit and/or valve connecter system.

[0023] The present invention further provides a solids removal system in an oil well, the system comprising a fluidisation jetting head adapted to be located in a solids bed at a bottom of the well, a first elongate conduit extending from the head and connectable to a supply of a fluidising liquid, a second elongate conduit extending from the head and connectable to a solids separation unit located above the well, wherein the head comprises a plurality of fluid outlet nozzles in fluid communication with the first elongate conduit and an inlet for a fluidised mixture of solids in the fluidising liquid in fluid communication with the second elongate conduit.

[0024] Typically, wherein the first and second elongate conduits are coaxial. Optionally, the first elongate conduit surrounds the second elongate conduit.

[0025] The present invention further provides a method of removing solids from an oil well, the method comprising the steps of:

a. locating a fluidisation jetting head, the head comprising a plurality of fluid outlet nozzles, in a solids bed at a bottom of the well;

b. supplying a fluidising liquid to the fluid outlet nozzles from a first elongate conduit extending upwardly from the head and connected to a supply of the fluidising liquid;

c. jetting the fluidising liquid out of the fluid outlet nozzles to fluidise solids in the vicinity of the head within the fluidising liquid to form a fluidised mixture of the solids in the fluidising liquid;

d. removing the fluidised mixture from the solids bed through an inlet of the head, the inlet being in fluid communication with a second elongate conduit extending upwardly from the head; and

e. conveying the fluidised mixture to a solids separation unit located above the well.

[0026] Typically, the first and second elongate conduits are coaxial. Optionally, the first elongate conduit surrounds the second elongate conduit.

[0027] Preferably, in step a the fluidising head is located at a first vertical position in a solids bed and after the solids content of the mixture has diminished the fluidising head is lowered to a second vertical position in the solids bed.

[0028] Typically, the fluidising liquid is supplied to the fluid outlet nozzles at an absolute pressure of from 0.5 to 2.5 bar. Typically, the fluidising liquid is supplied to the fluid outlet nozzles at a flow rate of from 50 to 250 l/min. The pressure and flow rate of the fluidising liquid may vary depending on the well depth, pipeline size, etc.

[0029] Typically, the fluidising liquid is water.

[0030] The present invention further provides an apparatus for separating solid particles from a hydrocarbon-containing fluid produced from an oil and/or gas production facility according to the present invention wherein the primary production conduit is in fluid communication with the second elongate conduit of the solids removal system according to the present invention.

[0031] The present invention further provides a method of removing solids from an oil well according to the invention wherein the fluid diverted in step ii comprises the fluidised mixture produced in step e of the method of removing solids from an oil well according to the invention.

[0032] The preferred embodiments of the present invention accordingly provide apparatus and methods that can integrate the flushing of low production well(s), the separation of solids removed, the separation of the produced gas from the oil, and the collection and boosting of the oil/gas produced from these wells so that it is co-mingled automatically with the production from other wells. Such a system can offer significant improvements over the prior art and allows improved production from a platform that is supporting a broad range of individual well production performance.

[0033] The preferred embodiments of the present invention provide a system comprising a well solids flushing or cleanout unit, a three-phase separator with storage and a pressure boosting unit.

[0034] The well solids flushing or cleanout may comprise dual coil tubing with an inner coil and an outer coil arranged concentric to each other. A single coil tubing could be used by reverse circulating down the annulus between the coil tubing and the well production tubing or casing. The dual coil tubing may have a fluidising jetting head that is at one end and fluid pumped down the annular space between the inner and outer coil tubing passes through the jetting head. In operation, the dual coil tubing is lowered into a well from which solids are to be flushed. Thereafter, the fluid pumped through the fluidisation jetting head fluidises the solids in the well and the mixture of solids and fluid are flushed out of the well through the inner coil tubing to the surface. The flushed mixture is directed to a solids separation and washing plant.

[0035] The preferred embodiments of the present invention also provide a three-phase separator with storage and a pressure boosting unit, which can be connected to the well solids flushing or cleanout unit. In these embodiments, oil produced from a low pressure well or wells can be treated by a three-phase separator to remove solids, generally sand, and gas and the oil is then collected in a fluid storage tank. The fluid storage tank can be equipped with a level sensor that provides a measure of the level of the fluids therein. The output of the level sensor can be connected to a controller that in turn is used to control a booster pump. The controller can maintain the level of collected fluid at some pre-determined level, e.g., at the mid-point in the tank, by adjusting the pump flow rate from zero to some maximum rate or start/stop the pump. A pressure sensor may be provided that measures the pressure of the oil production from the wells connected to a production manifold. The pressure sensor is connected to the controller and is used to adjust the booster pump output pressure so that the oil exiting is at a pressure just above the pressure in the production manifold so that oil passing through the three-phase separator is co-mingled with the oil produced by other wells on the platform. A non-return valve may be provided after the booster pump that prevents production fluids from returning into the storage tank. The non-return valve may also perform the function of ensuring the oil entering the production manifold is at the correct pressure above that of the flow in the production manifold.

[0036] The preferred embodiments of this invention can provide a method of flushing a well of solids, separating and washing said solids, collecting and boosting the cleaned produced oil/gas that comprise the steps:

1) Lowering a dual, outer and inner concentric coiled tubing with a fluidising jetting head into the well.
2) Pumping a fluid down the annulus between the outer and inner concentric coiled tubing to fluidise the solids into which the fluidising jetting head is lowered.
3) Collecting the flushed solids and fluidising fluid that exit up through the inner coiled tubing and directing them to a solids separation and washing plant.
4) Once the well has been cleaned of solids and begins flowing oil again, remove the coiled tubing from the well and direct the produced oil (which will contain some solids) to the three-phase separator with a storage tank.
5) Collecting the produced oil that has been cleaned of solids and gas in the storage tank.
6) Using a measurement of the fluid level in the tank to switch on a booster pump that moves oil from the storage tank once the level has risen above a predetermined level in the tank and stops pumping once the fluid level has dropped below a predetermined level.
7) Using a measurement of the pressure in the main oil production manifold to control the booster pump output pressure of the oil from the storage tank to that above the pressure in the manifold so that oil moved from the storage tank can be co-mingled with the main production from the platform.

[0037] Embodiments of the present invention will now be described in more detail by way of example only with reference to the accompanying drawings, in which:

Figure 1 schematically illustrates a side view of an oil and/or gas production platform for use with the apparatus and method of the present invention;

Figure 2 schematically illustrates a side view of a solids removal system according to an embodiment of the present invention;

Figure 3 schematically illustrates an end view of a fluidisation jetting head in the solids removal system of Figure 2; and

Figure 4 schematically illustrates a side view of a three-phase separator and pressure boosting apparatus according to an embodiment of the present invention.

[0038] Referring to Figure 1 there is shown a schematic of an oil and/or gas production platform, 103, with a four well template, 104, which has four wells, 105, drilled into various producing reservoirs 106 and 109. The seabed is labelled 101 and the sea surface is shown as 102. In Figure 1 all four wells are producing; however well 107 has depleted more rapidly than the others and as a result the flow rate from it is lower and solids produced, commonly sand, have not been fully removed from the well but have settled as illustrated by the solids bed labelled 108. Without some intervention to cleanout these solids, the well 107 will stop flowing completely resulting in lower production from the platform as a whole. In addition, as well 107 has depleted more rapidly, the pressure in the reservoir 109, is lower than in the other reservoirs 106, so that oil produced from well 107 is at a lower pressure. As a result the production from this well 107 cannot be directly co-mingled with the production from the other wells producing from 106 as this would result in flow from them flowing down well 107 and into the depleted reservoir 109.

[0039] Described hereinafter are various embodiments of the present invention which can overcome or resolve such limitations.

[0040] Referring to Figures 2 and 3 there is shown a schematic of a solids removal system 200 that may be used to remediate the well 107 in Figure 1.

[0041] The system 200 comprises a fluidisation jetting head 204 adapted to be located in a solids bed 203 at a bottom of the well 201. A first elongate conduit 207 extends from the head 204 and is connectable to a supply (not shown) of a fluidising liquid, such as water. A second elongate conduit 208 extends from the head 204 and is connectable to a solids separation unit (shown in Figure 3) located above the well 201. The head 204 comprises a plurality of fluid outlet nozzles 209 in fluid communication with the first elongate conduit 207 and an inlet 206 for a fluidised mixture of solids in the fluidising liquid in fluid communication with the second elongate conduit 208. The first and second elongate conduits 207, 208 are coaxial, and the first elongate conduit 207 annularly surrounds the second elongate conduit 208.

[0042] In Figure 2 the well 201 has a reduced production rate so that solids are no longer removed in the flow and have built up into a solids bed 203 over a period of time. A coiled tubing 202 consisting of two concentric tubes defining the first elongate conduit 207 and the second elongate conduit 208 is lowered into the well 201 so that the fluidisation jetting head 204 at its lower end is located within the solids bed 203. In this embodiment as show in Figure 2 the end of the jetting head 204 typically has eight fluid outlet nozzles 209. It will be appreciated by those skilled in the art that the number of nozzles 209 can be greater or less than this number and their sizes can be defined to provide appropriate jetting and fluidisation properties.

[0043] The dual concentric coiled tubing 202 has the outer annular conduit 207 defining an input flow channel and the inner circular conduit 208 defining an output flow channel. Fluid, generally water, is pumped down the annular conduit 207 and is jetted through the nozzles 209 into the solids bed 203 as illustrated by arrows 205. This fluidises the solids in the vicinity of the jetting head 204. The fluidised mixture of jetting fluid and solids exits through the inner circular conduit 208 of the dual coiled tubing 202 as illustrated by arrows labelled 206.

[0044] The fluidisation jetting head 204 is located at a first vertical position in the solids bed 203. After the solids content of the mixture has diminished, the fluidisation jetting head 204 can be is lowered to a second vertical position in the solids bed 203.

[0045] Typically, the fluidising liquid is supplied to the fluid outlet nozzles 209 at an absolute pressure of from 0.5 to 2.5 bar and/or at a flow rate of from 50 to 250 1/min. The pressure and flow rate of the fluidising liquid may vary depending on the well depth, pipeline size, etc.

[0046] As the solids bed 203 is removed, the coiled tubing 202 is progressively lowered further into the well 201 until the solids bed 203 is removed. The solids removed from the well 201 may be coated in hydrocarbons so must be separated and cleaned before they can be disposed of appropriately. Preferably, this is achieved using the apparatus and methods disclosed in UK patent application 1420257.6.

[0047] Once the solids bed 203 has been removed, the well 201 is no longer choked and can be brought back online so that is can produce more oil than before the remediation process. However, it will be understood by those skilled in the art that the production from this well will be at a lower pressure, because of the depletion of the reservoir, than other wells on the same production platform. Therefore, solids will likely start to build again but this may take some time and in the meantime economically viable additional oil production is achieved. In addition, further remediation can take place repeatedly using the same process as described herein.

[0048] Figure 4 shows a schematic of a three-phase separator and boosting apparatus that represents another embodiment of this invention.

[0049] In Figure 4 there is shown an apparatus for separating solid particles from a hydrocarbon-containing fluid produced from an oil and/or gas production facility. The facility comprises three wells 300, called wells 1, 2 and 3, connected to a primary production conduit in the form of a common manifold 309. It will be appreciated that there can be a larger or smaller number of wells 300 in any particular implementation.

[0050] The primary production conduit 309 having an upstream portion 320 and a downstream portion 322. At least one three-way valve 301 is connected to the upstream portion 320. The valve 301 has a first outlet 324 in fluid communication with the primary production conduit 309, a second outlet 326 in fluid communication with a solid particle separation unit, designated generally as 328, and an inlet 330 connectable to an oil and/or gas production well 300. The first and second outlets 324, 326 of the valve 301 are selectively connectable to the upstream end 320 or the solid particle separation unit 328. The or each valve 301 is actuatable to select between the respective first and second outlets 324, 326.

[0051] The at least one valve 301 comprises a plurality of three-way valves 301 connected to the upstream portion 320. Each three-way valve 301 has a first outlet 324 in fluid communication with the primary production conduit 309, a second outlet 326 in fluid communication with the solid particle separation unit 328, optionally via an on/off valve 302, and an inlet 330 in use connected to an oil and/or gas production well 300. The first and second outlets 324, 326 of each three-way valve 301 are selectively connectable to the upstream portion 320 or the solid particle separation unit 328, and the plurality of three-way valves 301 are individually actuatable to select between the respective first and second outlets 324, 326.

[0052] A pressure sensor 344 may detect fluid pressure in the valve inlet 330. A valve control 346 may be provided for switching the inlet 330 into fluid communication with the second outlet 326 when the detected fluid pressure is below a pre-set pressure threshold or when a pressure difference between the detected pressure and pressure in the primary production conduit 309 is above a pre-set minimum pressure difference.

[0053] The solid particle separation unit 328 has a common manifold 310 to which each second outlet 326 is connected either directly or by an intermediate conduit and/or valve connecter system.

[0054] The solid particle separation unit 328 comprises at least one solid separator 303, 304 and having a first output for solids 306 and a second output 332 for fluids. The second output 332 is in fluid communication with an input 334 of a fluid separator 305 having a liquid output 336 and a gas output 338. The liquid output 336 is in fluid communication with the downstream portion 322 by a return conduit 340.

[0055] A controller 313 is provided for controlling liquid flow from the fluid separator 305 to the downstream portion 322 along the return conduit 340.

[0056] A pressure boosting pump 308 is located in the return conduit 340 for pressurising liquid in the return conduit 340 and pumping the pressurised liquid in the return conduit 340 in a direction from the fluid separator 305 to the downstream portion 322.

[0057] The controller 313 is adapted to control any one or more, in any combination, of any of an output pressure of the pump 308; a flow rate of the pump 308; and an on/off function of the pump 308.

[0058] In this embodiment, the controller 313 is adapted to control the output pressure of the pump 305 so as to be above the liquid pressure in the primary production conduit 309, preferably by a pre-set minimum pressure difference.

[0059] A pressure sensor 312 for measuring liquid pressure in the primary production conduit 309 is connected to the controller 313 to output a pressure signal to the controller 313 to control the output pressure of the pump 308.

[0060] A reservoir sensor 311, preferably a liquid level sensor, measures a liquid amount in a reservoir 342 of the fluid separator 305. The controller 313 outputs a control signal to control liquid flow from the fluid separator 305 to the downstream portion 322 along the return conduit 340 when the liquid amount is above a pre-set threshold. The control signal is adapted to cause or permit liquid flow from the fluid separator 305 to the downstream portion 322 when the liquid level in the reservoir 342 of the fluid separator 305 is above a pre-set threshold level. The control signal may maintain the liquid level in the reservoir 342 of the fluid separator 305 above a pre-set minimum threshold level and/or below a pre-set maximum threshold level.

[0061] The pump 308 may be configured to restrict liquid flow from the downstream portion 322 to the fluid separator 305 along the return conduit 340, for example by having a non-return construction. In the illustrated embodiment, a non-return valve 314 is located in the return conduit 340 between the pump 308 and the primary production conduit 309 to restrict, preferably to prevent, liquid flow from the downstream portion 322 to the fluid separator 305 along the return conduit 340. The non-return valve 314 may be self-regulating to open to provide flow therethrough in a forward direction at a pre-set pressure difference across the non-return valve 314. Alternatively, the controller 313 may be adapted to control the non-return valve 314 to open to provide flow therethrough in a forward direction at a pre-set pressure in the return conduit 340 upstream of the non-return valve 314 or at a pre-set pressure difference across the non-return valve 314. The controller 313 may be adapted to control the non-return valve 314 to open to provide flow therethrough in a forward direction when the pre-set pressure in the return conduit 340 upstream of the non-return valve 314 is above the liquid pressure in the primary production conduit 309 by a pre-set minimum pressure difference.

[0062] A gas compressor 316 is optionally coupled to the gas output 338 of the fluid separator 305 for providing a supply of compressed gas from the fluid separator 305. Typically, an outlet 307 of the gas compressor 316 is coupled to a gas production conduit (not shown) of the gas production facility. The controller 313 may be adapted to control the output pressure of the gas compressor 316 so as to be above the gas pressure in the gas production conduit, optionally by a pre-set minimum pressure difference.

[0063] Accordingly, there is provided sets of three-way valves 301 and on/off valves 302 that allows flow from any well or group of wells 300 to be directed either to the main production manifold 315 or through a second manifold 310 to the three-phase separator and booster. The pressure in the manifold 310 can be lower, for example at atmospheric pressure, than the pressure in the production manifold 309. If flow from well 1 is from a depleted reservoir producing at a lower pressure and is also producing sand as described in other embodiments of this invention, then the flow from this well is no longer directed into the main production manifold 309 but is directed through manifold 310 into the separator and boosting system. This is achieved by adjusting valve 301 at well 1 and opening valve 302 at well 1 so that flow from well 1 no longer enters main production manifold 309 but is directed to manifold 310.

[0064] Flow from the manifold 310 is first directed into a first solids separation apparatus 303 as shown in Figure 4. Preferably the separator is as described in UK patent application 1420257.6, however, it will be appreciated by those skilled in the art that this can be another type of solids separator. The fluid that has had the solids removed exits the top of 303 and is directed into a second solids separator 304. In some implementations a single solids separator will suffice but in others more than two may be required but preferable a system of two solids separators is used. The solids separated from the flow by 303 and 304 are collected at the bottom of the separators and exit the system as shown by arrow 306. The fluid further cleaned of solids exits 304 and is fed into an oil/gas separator and fluid storage tank 305 in Figure 4.

[0065] Gas separated from the flow will exit 305 at the top as labelled 307 and will be collected or flared in a manner well known. Optionally, a compressor 316 is used to raise the pressure of the gas to that of other produced gas on the platform so the collected gas is co-mingled with the main gas production.

[0066] The separated oil will collect in the bottom of the tank 305 which is fitted with a level sensor 311 as described in other embodiments of this invention and is schematically illustrated. Also the pressure in the main production manifold 309 is measured using a pressure sensor 312. Both the fluid level in oil/gas separator and fluid storage tank 305 and the pressure measured in manifold 309 are connected to a controller 313. Additionally there is provided a booster pump 308 also connected to the controller 313. The controller is programmed to use these measurements to maintain the level in the storage tank 305 at some predefined level, e.g., half way up the tank. Once the fluid level in storage tank 305 reaches some defined level above the mid-point the controller 313 activates the booster pump 308 and fluid pumped from storage tank 305 is increased to a pressure above that of the main production flow in manifold 309 and as measured by pressure sensor 312. The booster pump 308 continues to reduce the level of the fluid in storage tank 305 until it reaches a predefined level below the mid-point at which time the booster pump 308 stops pumping. Non-return valve 314 prevents production fluid returning back towards the three-phase separator. This non-return function may be a feature of the booster pump 308 itself. With the booster pump 308 switched off, the level in storage tank 305 starts to increase again as production from well 1 continues and is passed through separators 303, 304. Once the liquid level in storage tank 305 increases to the predefined level over the mid-point again, the booster pump 308 is activated and the cycle is repeated. The controller 313 can be linked to a display, not shown, where the measured parameters and pump status can be displayed. Preferably the booster pump 308 is activated automatically as described but it could be switched on and off manually by an operator who is acting in response to the measured data displayed.

[0067] In a simpler form, the pressure sensor 312 is not required and the booster pump 308 increases the pressure of the oil removed from the storage tank 305 by pumping against non-return valve 314. Once the pressure of this oil is above that of the oil in the production manifold 309, the non-return valve 314 opens and the boosted oil from storage tank 305 enters the main production stream 315. In this case the booster pump 308 is controlled using the controller 313 that only uses the measured fluid level in storage tank 305 provided by the sensor 311. In this embodiment the pressure sensor 312 is absent from Figure 4 and the controller 313 has a single input from sensor 311 and the output signal from 313 will switch the booster pump 308 on and off or controls its speeds as illustrated in Figure 4 and described earlier using the fluid level in storage tank 305.

[0068] The collected production in storage tank 305 from the low pressure well 1 is first cleaned of solids and gas as described and then boosted to a pressure so that it may be co-mingled with the production from the other wells, e.g., wells 2 & 3, to contribute to the overall production from the platform as illustrated by 315.

[0069] Using the apparatus and method of the preferred embodiment described herein, a low producing oil well or group of oil wells, that have been impacted by the build-up of solids within the well or wells can be remediated to have the solids removed and cleaned. In extreme situations the well or wells may even stop producing oil because of this build-up and after remediation can return to producing some oil. The production from this low production well or wells can then be cleaned of any produced solids, which is generally sand, and any produced gas. Thereafter the produced oil is collected then boosted to a higher pressure so that it can be co-mingled with the oil produced from other wells on the same platform. Such a system will allow these wells to continue to produce oil albeit at a low rate and to contribute to increasing the overall production of the platform. This also extends the life of the platform and provides significant advantages over present day practice.

[0070] The present invention may be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the invention to those skilled in the art.

Claims

1. A solids removal system in an oil well, the system comprising a fluidisation jetting head adapted to be located in a solids bed at a bottom of the well, a first elongate conduit extending from the head and connectable to a supply of a fluidising liquid, a second elongate conduit extending from the head and connectable to a solids separation unit located above the well, wherein the head comprises a plurality of fluid outlet nozzles in fluid communication with the first elongate conduit and an inlet for a fluidised mixture of solids in the fluidising liquid in fluid communication with the second elongate conduit, wherein the plurality of fluid outlet nozzles surround the inlet and are downward facing.

2. A solids removal system according to claim 1 wherein the first and second elongate conduits are coaxial.

3. A solids removal system according to claim 2 wherein the first elongate conduit surrounds the second elongate conduit.

4. A method of removing solids from an oil well using the solids removal system of claim 1, the method comprising the steps of:

   a. locating the fluidisation jetting head, the head comprising a plurality of fluid outlet nozzles, in a solids bed at a bottom of the well;
   b. supplying a fluidising liquid at an absolute pressure of from 0.5 to 2.5 bar and a flow rate of from 50 to 250 1/min to the fluid outlet nozzles from the first elongate conduit extending upwardly from the head and connected to the supply of the fluidising liquid;
   c. jetting the fluidising liquid out of the fluid outlet nozzles downwardly to fluidise solids in the vicinity of the head within the fluidising liquid to form a fluidised mixture of the solids in the fluidising liquid;
   d. removing the fluidised mixture from the solids bed through the inlet of the head surrounded by the plurality of fluid outlet nozzles, the inlet being in fluid communication with the second elongate conduit extending upwardly from the head; and
   e. conveying the fluidised mixture to the solids separation unit located above the well.

5. A method according to claim 4 wherein the first and second elongate conduits are coaxial.

6. A method according to claim 5 wherein the first elongate conduit surrounds the second elongate conduit.

7. A method according to any one of claims 4 to 6 wherein in step a the fluidising head is located at a first vertical position in a solids bed and after the solids content of the mixture has diminished the fluidising head is lowered to a second vertical position in the solids bed.

8. A method according to any one of claims 4 to 7 wherein the fluidising liquid is water.

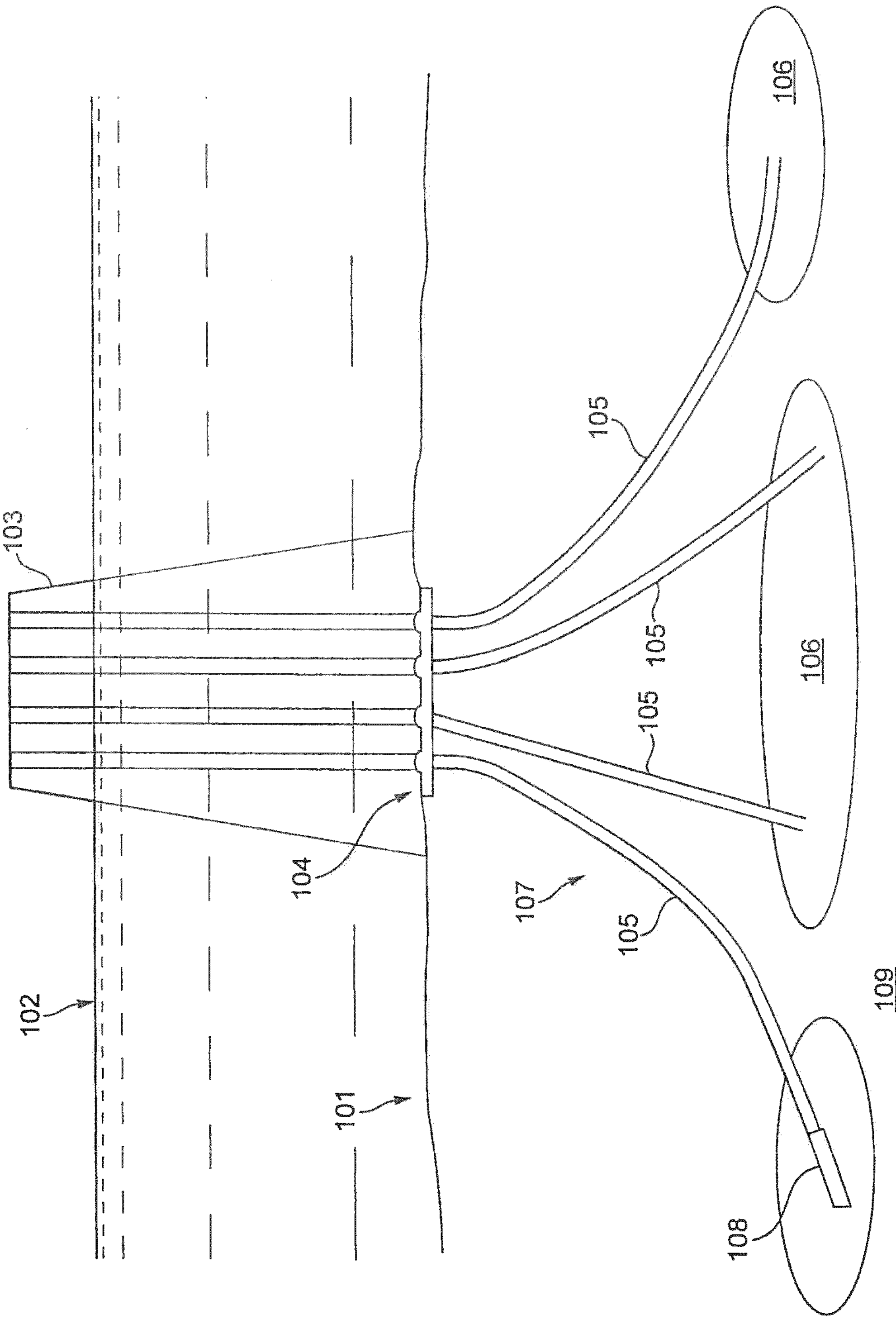

FIG. 1

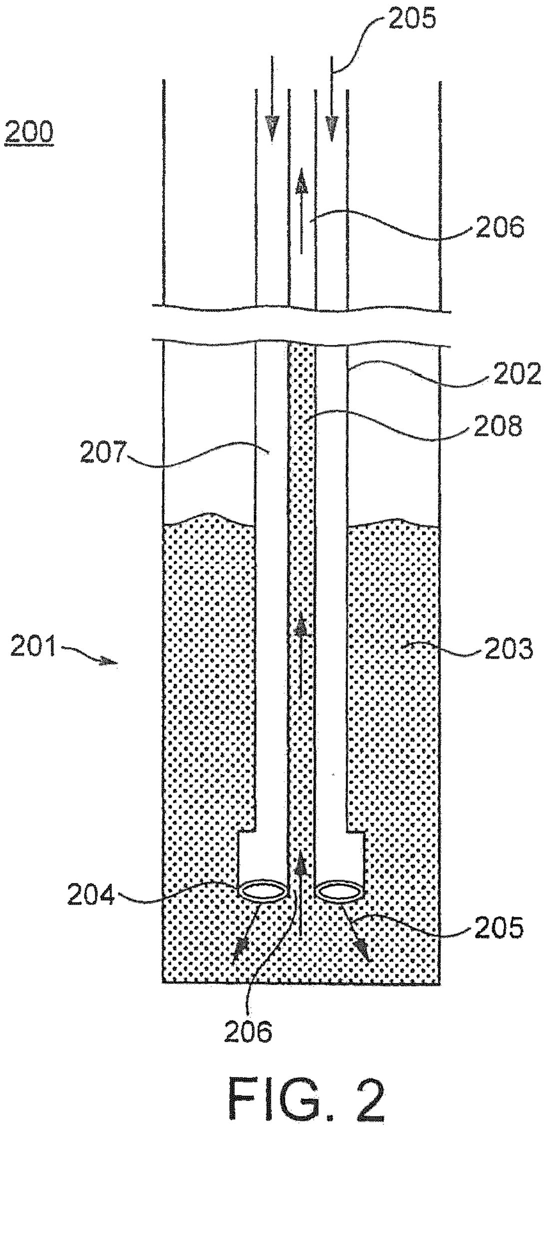

FIG. 2

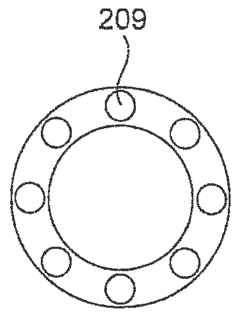

FIG. 3

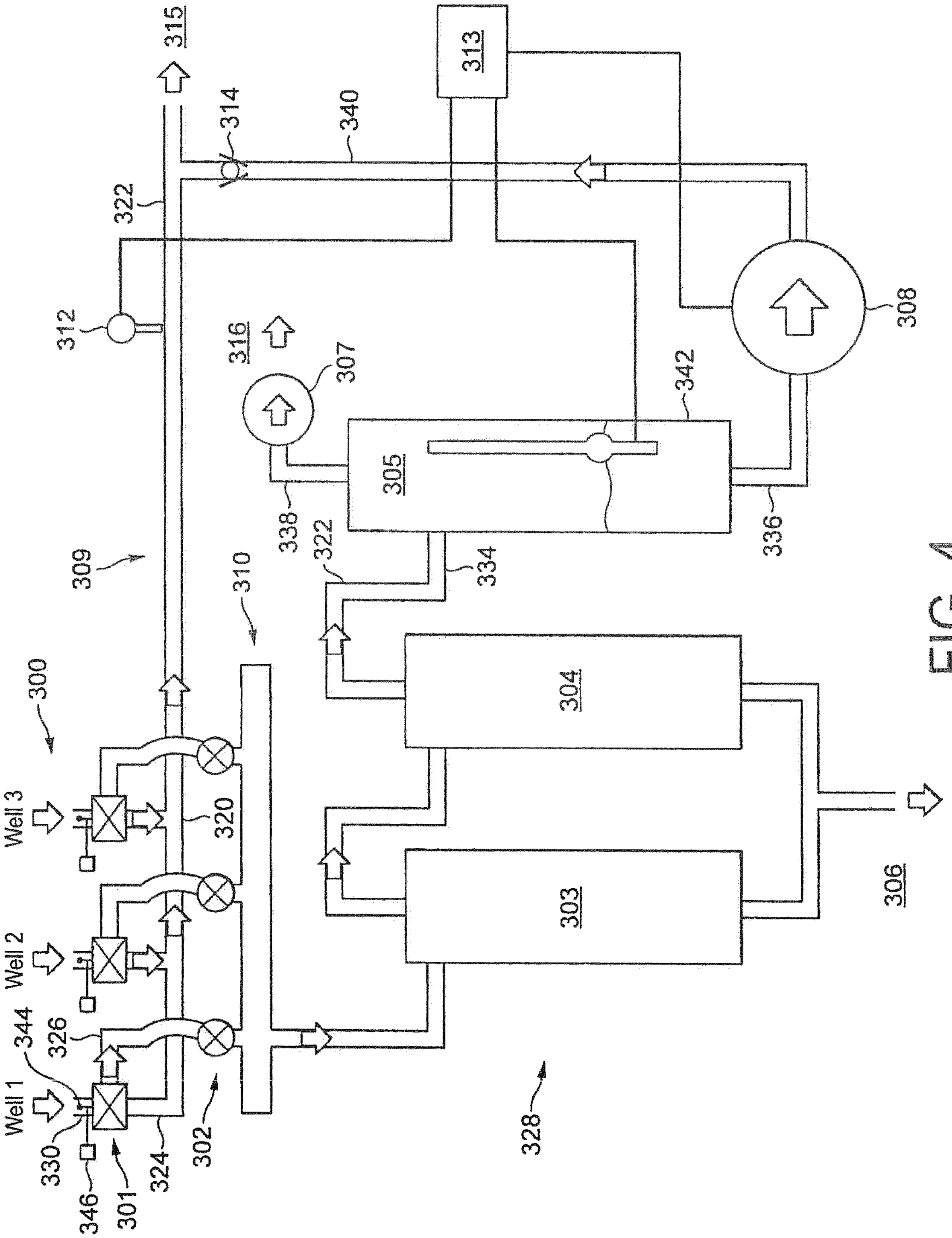
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FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
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1

Place of search	Date of completion of the search	Examiner
Munich	21 October 2019	Pieper, Fabian

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