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LIQUID/SOLID SEPARATION

5 The production fluid from an oil well includes varying proportions of oil, water and gas in which are entrained solid particles, hereinafter referred to as "sand". This mixture is normally fed to a phase separator in which settling under gravity occurs into an upper gaseous layer, a middle oil layer, and an lower water layer. These are removed through separate outlets from the separator. The sand naturally settles out in the bottom of the water layer in the tank and it will be undesirable to allow this to be discharged through the water outlet, not least because the sand particles will be coated with oil and it is unacceptable to discharge such coated particles with the water back into the environment. Consequently the coated sand particles are recovered from the bottom of the phase separator and, according to one method, supplied to a vessel fitted with impellers which rotate in opposite directions to suspend the contaminated particles in water, causing dynamic contact of the particles, which mechanically strips away the oil coatings from the solid particles. The clean solid particles may then be discharged to the environment but the carrier water has to be treated, normally by flotation, to remove the oil. This is difficult, costly, and takes space which is at a premium on, for example, a marine platform.

Other situations obtain where it is necessary to clean oil-coated sand particles, for example when an oil spillage contaminates a beach.

According to the present invention, a method for separating oil from particles coated with oil comprises loading the coated particles into a housing containing a fluidising unit which has a liquid supply duct with an outlet and arranged to be fed with water under pressure from outside the housing, and a discharge duct within the liquid supply duct having at its end an inlet projecting

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beyond the outlet of the liquid supply duct, the discharge duct leading to a separator; feeding water to the liquid supply duct and causing it to swirl at the outlet such that it disturbs the oil and sand particles to cause the oil to be stripped, at least partially, from the particles, and causes the oil and sand particles entrained in the water to travel into the discharge duct and hence to a separator, where the oil, water and solid particles undergo separation.

10 The fluidising unit creates a swirling vortex which violently strips oil from the sand particles and also discharges the oil, water and sand without the need for any moving parts in contact with the separated components.

15 Although the method may be used for example, for cleaning sand from a contaminated beach after an oil spill, or for cleaning drilling mud, so that the mud is clean enough to be dumped, it is particularly useful for treating the oil-coated sand sedimented in a three phase separator for separating the components of the production fluid from an oil well. Alternatively, the contaminated sand in the production fluid may be treated by the method after settlement of the contaminated sand from the production fluid prior to its entry into the three phase separator. In these cases, the water fed to the liquid supply duct of the fluidising unit is preferably taken from the water outlet of the phase separator. This has the advantage that the water will still be at a comparatively high temperature, which will promote the stripping of the oil coating from the sand particles.

25 The separator may include a centrifuge or a single hydrocyclone stage which is arranged such that the oil is substantially separated and reports to the overflow and the water and sand report to the underflow. However, to improve the separation, two hydrocyclone stages are preferably provided, the first of which is a liquid/solid separation hydrocyclone, which substantially separates sand, which reports to the underflow from oil and water,



which report to the overflow, and the second of which is a liquid/liquid separation hydrocyclone, which substantially separates water which reports to the underflow from oil which reports to the overflow. The use of hydrocyclones
5 generates sufficient centrifugal forces to cause further scrubbing of the oil from the sand particles.

The efficiency of solid/liquid separation hydrocyclones is critically dependent upon the density of slurry fed to the hydrocyclone inlet. The present
10 invention, utilising the special fluidising unit, is particularly suitable for maximising the efficiency of a solid/liquid separation hydrocyclone in the separator because the density of the slurry discharged through the discharge duct of the fluidising unit can be accurately
15 controlled by fine tuning the parameters of the fluidising unit. The particular parameters which are either preset for a particular system, or are adjustable to accommodate changing conditions are the pressure/flow of the water fed to the liquid supply duct of the fluidising unit, and the
20 axial separation of the outlet of the liquid supply duct and the inlet of the discharge duct of the fluidising unit.

One aspect of the invention includes an apparatus for carrying out the method according to the present invention, the apparatus comprising a housing having an inlet for oil-
25 coated sand particles, the housing containing a fluidising unit which has a liquid supply duct with an outlet and arranged to be fed with water under pressure from outside the housing, and which has a discharge duct within the liquid supply duct and having at its end an inlet
30 projecting beyond the outlet of the liquid supply duct, the discharge duct leading to a separator comprising a liquid/solid separation hydrocyclone, the overflow outlet of which leads to a liquid/liquid separation hydrocyclone.

A further aspect of the invention includes an
35 apparatus for carrying out the method according to the present invention, the apparatus comprising a housing having an inlet for oil-coated sand particles, the housing



containing a fluidising unit which has a liquid supply duct with an outlet and arranged to be fed with water under pressure from outside the housing, and which has a discharge duct within the liquid supply duct and having at its end an inlet projecting beyond the outlet of the liquid supply duct, the discharge duct leading to a separator; and a three phase separator, to which an overflow from the housing leads. This apparatus is suitable for use with the method which treats the production fluid prior to its entry into the three phase separator. The separator may be a centrifuge, or a solid/liquid hydrocyclone, the overflow of which leads to the three phase separator. Water from the three phase separator may be supplied to the liquid supply duct of the fluidising unit. In order to improve the settlement of sand within the housing, the inlet for oil-coated sand particles preferably leads to a cyclonic separator, the underflow of which discharges sand with some associated fluids to a lower portion of the housing, and the overflow of which discharges oil and water, substantially free of sand, to an upper part of the housing.

This arrangement forms an independent aspect of the present invention which may be defined as a separator for separating solid particles from a mixture containing solid particles and a fluid component, such as a production fluid containing sand particles, the separator comprising a housing having an inlet for the mixture and a separated fluid outlet associated with an upper part of the housing; the inlet for the mixture leading to a cyclonic separator such that the mixture is caused to swirl in the cyclonic separator, the cyclonic separator having an overflow for the discharge of fluids to an upper part of the housing, and an underflow for the discharge of solid particles and some fluid to a lower part of the housing; and, associated with the lower part of the housing, a fluidising unit which has a liquid supply duct with an outlet and arranged to be fed with liquid under pressure from outside the housing,

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and which has a discharge duct within the liquid supply duct and having at its end an inlet projecting beyond the outlet of the liquid supply duct.

5 A plurality of baffles may be provided in the housing to provide a tortuous path to the upper part of the housing for any fluid discharged from the underflow of the cyclonic separator, and which deter any solid particles discharged from the underflow of the cyclonic separator from reaching the upper part of the housing. If the mixture is, for
10 example, a production fluid which forms a gas core in the cyclonic separator, then it is advantageous to provide a gas overflow outlet positioned on the axis of the cyclonic separator.

Alternatively the housing of the separator is formed
15 as a pressure vessel; and the cyclonic separator is at least one hydrocyclone, the underflow outlet or outlets of which discharge(s) into a closed underflow chamber of the pressure vessel, in which chamber the fluidising unit is provided.

20 If there is a bank of more than one hydrocyclone within the pressure vessel, the inlet for the mixture to the vessel may open into an inlet chamber and the overflow outlets of the hydrocyclones may open into an overflow chamber, the inlet and overflow chambers being sealed from
25 one another and from the underflow chamber.

By its nature, the hydrocyclone provides a pressure drop from its inlet to its underflow and overflow outlets, the pressure drop to the overflow outlet in a solid/liquid separating cyclone, normally being greater than that
30 between the inlet and underflow chambers. Consequently, and according to a preferred aspect of the invention, an upper part of the underflow chamber is connected to an overflow outlet from the vessel in order that any gas or oil carried through the hydrocyclone underflow into the
35 underflow chamber flows to and is entrained by the fluids leaving the overflow outlet for fluids from the vessel.



A further advantage of the pressure drop between the production fluid inlet pressure and the pressure obtaining in the underflow chamber may be obtained by driving the fluidising unit with the inlet pressure, that is by
5 connecting the supply duct of the fluidising unit to a mixture inlet line to the vessel so that a side stream of the mixture drives the fluidising unit. In this way a small proportion of the excess pressure in the mixture is used up in driving the fluidising unit, without the need
10 for any separate pressure source.

Fluidising units of a type suitable for use in any aspect of the present invention are disclosed in our earlier US-A-4978251, 4952099 and 4992006. The fluidising unit is capable of removing particles on line, without the
15 need to depressurise the housing.

The fluidising units of any aspect of the present invention may be orientated with the liquid supply duct and discharge duct opening downwardly. Alternatively, the fluidising unit may be orientated with the liquid supply
20 duct and the discharge duct opening upwardly. In this case, it is preferable to close the gap between the liquid supply duct unit is not in use. The gap can be closed by a valve which may be biased closed and forced open by liquid in the liquid supply duct, or by the liquid supply
25 duct being movable with respect to the discharge duct to close the gap.

In any aspect of the present invention the swirl of the liquid at the outlet of the liquid supply duct may be caused by inclined vanes in the liquid supply duct, and/or
30 by the liquid supply duct having a tangential inlet into a cylindrical chamber upstream of the liquid supply duct outlet.

In the fluidising unit used with any aspect of the present invention, a jet pump can be provided on the
35 discharge duct to boost the pressure in the discharge duct. When the discharge duct leads to a cyclone separator, the liquid supplied to the jet pump can be controlled to

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control the liquid/solid ratio to that required by the cyclone separator.

In any aspect of the present invention, to enhance further the scrubbing of the oil from the sand particles, chemicals may be added to the liquid which is fed to the liquid supply duct of the fluidising unit.

In any aspect of the present invention, in order to accommodate varying sand loads, the amount of sand in the housing may be sensed, for example using a vibrating probe to sense the level of sand or a load cell to sense the mass of sand, so that the fluidising unit can be operated when the amount of the sand within the housing reaches a threshold value.

By removing abrasive particles by any aspect of the present invention, expensive upstream equipment and valves are protected from abrasive damage.

Examples of systems employing the method of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a first system;

Figure 2 is a schematic diagram of a system in which the first system is used for de-oiling sand from a phase separator;

Figure 3 is a schematic diagram of a system in which a modified version of the first system is used for de-oiling sand to a phase separator;

Figure 4 is an axial section of a housing including a sand trap which is a modified version of that shown in Figure 3; and

Figure 5 is an axial section of a housing including a sand trap which is a modified version of that shown in Figure 3.

In Figure 1, a housing 1 has an inlet 2 for sand contaminated with oil.

A fluidising unit 3 is provided within the housing 1. The unit has a liquid outlet 4 which is fed with water by a liquid supply duct 5. The liquid supply duct 5 is



provided with means such as inclined vanes (not shown) for swirling the liquid discharged from the liquid outlet 4. A discharge duct 6 is located within and is coaxial with the liquid supply duct 5. The discharge duct 6 terminates in an inlet 7 which projects beyond the liquid outlet 4.

The discharge duct 6 leads to a first hydrocyclone stage 8 which is arranged to separate sand at its underflow 9 from oil and water at its overflow 10. The hydrocyclone stage 8 has one or more solid/liquid hydrocyclones typically constructed of polypropylene or a ceramic material. The sand from the underflow 9 is discharged into a container 11 from which it can be discarded through a nozzle 12. Excess water can be drained through a second nozzle 13. The oil and water from the overflow 10 of the first hydrocyclone 8 are fed to a second hydrocyclone stage 14 where the water at the underflow 15 is separated from the oil at the overflow 16. The second hydrocyclone stage 14 has one or more liquid/liquid hydrocyclones of the type described in GB 2221408. The hydrocyclones 8,14 may be fitted with ceramic components at points of high erosion potential.

The oil from overflow 16 will still contain some water. It is therefore fed to a tank 17 having first 18 and second 19 chambers. The first chamber has a water discharge line 20 the flow through which is controlled by a valve 21. The second chamber 19 has an oil discharge line 22. An overflow line 23 leads from the housing 1 to the first chamber 18 of the tank 17.

A water recycling system 24 is provided with a pump 25 which receives water from nozzle 13, underflow 15 and water discharge line 20 and pumps it to the liquid supply duct of the fluidising unit 3.

In use, the sand particles contaminated with oil are loaded into the housing 1 through the inlet 2. Once there is sufficient contaminated sand in the housing 1, the fluidising unit 3 is activated. This involves supplying water under pressure to the liquid supply duct 5. The



water is caused to swirl as it leaves the liquid outlet 4 thereby generating a precessing vortex core directly under the inlet 7 of the discharge duct 6. The precessing vortex core causes violent pulsating forces which both fluidise and mix the contaminated sand in the zone of influence of the core. The mixing action causes the sand particles to contact each other with sufficient energy to scrub away some or all of the oil coating from the sand. Typically, about half of the water fed to the fluidising unit 3 is discharged through the discharge duct 6 with the sand particles while the rest of the water remains in the housing 1 in place of the discharge sand. The addition of appropriate chemicals to the liquid supply duct 5 facilitates this scrubbing action. The precessing vortex core causes the sand and oil entrained in the water to be discharged from the housing through discharge duct 6.

The oil, sand and water from the discharge duct 6 encounter the first hydrocyclone stage 8 where the sand is separated from the oil and water and reports to the underflow 9. The oil and water report to the overflow 10 and encounter the second hydrocyclone stage 14 wherein the water reports to the underflow 15 and the oil is discharged through overflow 16 to the first chamber 18 of tank 17. The valve 21 remains closed until the fluids in the first chamber 18 reach a level to allow the upper layer of oil to flow into the second chamber 19. The valve 21 can be operated automatically using a level control which detects the position of the water-oil interface within the first chamber 18. The oil in the second chamber 19 is discharged through line 22 for recovery. The water from the first chamber 18 is discharged through line 20 on opening of the valve 21 and may be fed to the liquid supply duct 5 of the fluidising unit 3 through water recycling system 24, driven by pump 25.

Figure 2 shows the system of Figure 1 being used to de-oil sand extracted from a three phase separator 26. Such a phase separator may be used to separate fluids from

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an oil well which are contaminated with sand. The sand will tend to settle to the bottom of the separator 26 thereby reducing the effective volume and clogging the ports of the phase separator. The sand which is removed
5 will be contaminated with oil.

The phase separator 26 has conventional gas 27, oil 28 and water 29 outlets. In addition, an outlet 30 leading to housing 1 is provided for the contaminated sand which has settled on the bottom of the tank. A water inlet 31 which
10 allows water into the phase separator 26 in order to flush out the sand and oil through outlet 30 is connected to a pump 32.

A load cell 33 detects the mass of the contents of housing 1 and outputs a signal to a controller 34 which
15 gives an indication of the amount of sand in the housing 1. The load cell 33 could equally be replaced by a vibrating probe sensor within the housing 1 to detect the level of sand within the housing 1.

The controller 34 receives additional signals from
20 first 35 and second 36 flow sensors, which detect abnormal flow conditions in the system, and sends signals to a plurality of valves, the pump 32 and a chemical dosing unit 37 in a manner to be described. The remainder of the system is as described with reference to Figure 1.

25 The size of the fluidising unit used and the length of time for which it is run depends on the content of sand within the oil. For example, in an oil field where the sand load is light (less than 0.5 tonnes/day), a fluidising unit having an inlet 7 with a 25 mm bore may typically be
30 run for about two hours a week. Where the sand load is medium (up to 20 tonnes/day) the same fluidising unit is typically run for twelve hours a day. Where the sand load is heavy (greater than 20 tonnes/day) a fluidising unit in which the inlet 7 has a 50 or 75 mm bore might be run for
35 up to twelve hours a day.

In order to remove the sand from the phase separator 26, the pump is run at a first speed to pump water through



the line 31 to flush out the contaminated sand from the bottom of the phase separator 26 through outlet 30 and into the housing 1. The heavy sand sinks to the bottom of the housing 1, while the oily water overflows through the overflow line 23 to a slop tank, or for further treatment. As the housing 1 fills with sand and the oily water is displaced, the overall mass increases. The increasing mass is sensed by the load cell 33 or the increasing level of sand is sensed by a vibrating probe, and, when the amount reaches a threshold value, the controller 34 shuts off the supply of water from the pump 32 to the phase separator 26 so that the flushing operation is terminated. The pump 32 is then run at a second speed which is lower than the first speed to pump water to the liquid supply duct 5 of the fluidising unit 3. This causes the contaminated sand to be scrubbed and removed from the housing 1 and separated as described with reference to Figure 1. If the sand load is unusually light, the amount may not reach the threshold value, in which case, the flushing operation will be terminated by a timer.

As the fluidising unit 3 discharges the sand from the housing 1, the amount of sand within the housing will fall until a value is detected indicating that there is no sand present within the housing, at which point the system will be shut down until the cleansing of the separator 26 is required again.

In place of the double hydrocyclone stage 8,14 shown in Figure 2. It is possible to use a single hydrocyclone stage in which the oil reports to the overflow and the water and sand report to the underflow.

Figure 3 shows a system for removing the bulk of the sand, for example, particles having a diameter of more than 0.1 mm, from the production fluid of an oil well before it enters a three phase separator. This system includes a system similar to that shown in Figure 1 although it is only shown with a single hydrocyclone stage, the overflow



of which leads to the inlet of the three phase separator instead of the tank.

5 The production fluid from the oil well enters a sand trap 38 in the housing 1. The contaminated sand settles to the bottom of the housing, while the liquid part of the production fluid overflows from the housing 1 through overflow 23 which leads to the inlet of the three phase separator 26. A detector 39 detects when the level of sand in the housing is at a predetermined level and the fluidising unit 3 is operated in the same manner as described with reference to Figure 1. The discharge duct 6 of the fluidising unit 3 leads to a first hydrocyclone 40 which separates the sand and water, which report to the underflow 41 from the oil and some water which report to the overflow 42. The clean sand and water from the underflow 41 encounter a degas stage 43 before being dumped. The oil and water from overflow 42 are pumped back to the inlet of the three phase separator 26.

20 Water taken from the water outlet 29 of the three phase separator 26 is fed to liquid/liquid hydrocyclone 44, and the cleaned water from the underflow 45 is fed to the liquid supply duct, after being supplied with the appropriate chemicals from chemical dosing unit 37. If the fluidising unit 3 is not being run, the operation of appropriate valves ensures that the water from the underflow 45 is not supplied to the liquid supply duct 5, but is instead dumped after encountering degas stage 46. Oil containing a water component is discharged from the outlet 47 of the hydrocyclone 44 and is pumped to the inlet of the three phase separator 26.

35 A second fluidising unit 48 which operates in the same way as the fluidising unit 3, previously described, is provided in a trap 49 in the bottom of the three phase separator 26. This unit 48 operates in the same way as the fluidising unit 3 previously described, and is used to clean the three phase separator 26 during normal shut downs, or, if for some reason sand is carried over into the



three phase separator 26 from the housing 1. The contaminated sand removed by the second fluidising unit 48 is dealt with in the same way as that from the first fluidising unit 3.

5 A modified version of the sand trap 38 is illustrated in Figure 4. This shows a housing 1 having a fluidising unit 3 and an overflow line 23 as shown in the previous examples.

10 The inlet 2 for production fluid leads tangentially to a cyclonic separator 50 such that the production fluid is caused to swirl. The cyclonic separator 50 has an overflow 51 for oil, gas and some water. A second overflow 52 is provided for gas which forms in core at the axis of the cyclonic separator 50. A choke valve 53 controls the
15 outlet of the gas. This gas will be quite wet and will therefore require a gas dehydration device to remove liquids prior to the gas being set to flair. Any liquids removed are sent to the three-phase separator 26.

20 The underflow 54 of the cyclonic separator discharges the majority of the sand together with some water, oil and gas towards a lower part of the housing 1. A baffle 55 distributes the sand, which is thrown outwards by the swirling action in the cyclonic separator 50, around the lower part of the housing 1. A series of further baffles
25 56 create a tortuous path through which any water, oil or gas from the underflow 54 flows back to the top part of the housing 1. This tortuous path deters the sand from migrating to the top of the housing.

30 As shown a pressure vessel 1 has an inlet 2 for production fluid, leading into an inlet chamber 57 which is sealed by walls 58 and 59 from an overflow chamber 60 having an outlet 23, and an underflow chamber 61. Supported by the walls 58 and 59 are a bank of hydrocyclones 62, of which only two are shown. Each has
35 its inlet 63 open to the chamber 57, its overflow outlet 64 discharging into the chamber 60, and its underflow outlet 65 discharging into the chamber 61. The hydrocyclones 62



are designed primarily to separate sand from fluid, the majority of the fluid passing into the overflow chamber 60 and out of the outlet 23 whilst the majority of the sand with some fluid, including water, oil and gas passes into the underflow chamber 61 where the sand sediments in the bottom of the chamber 61. From here it may be continuously or intermittently discharged by means of a fluidising unit 3 similar to that shown in Figure 4.

The primary production fluid supplied to the inlet 2 is via a main line 66. A branch 67 is taken off this line and is connected to the liquid supply duct 5 via a control valve 68 to drive the fluidising unit.

Inevitably some gas and oil will collect in the top of the underflow chamber 61 and as this chamber will be at a somewhat higher pressure than obtaining in the outlet chamber 60 and outlet 23, it may be removed via an outlet 69 connected via a line 70 to the main outlet line 71 leaving the outlet 23. In this way the chamber 61 can be purged of lighter fluids, heavier fluid, particularly water, being discharged through the discharge duct 7 from the fluidising unit 3.

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CLAIMS

1. A method for separating oil from particles coated with oil, the method comprising loading the coated particles
5 into a housing (1) containing a fluidising unit (3) which has a liquid supply duct (5) with an outlet (4) and arranged to be fed with water under pressure from outside the housing, and a discharge duct (6) within the liquid supply duct having at its end an inlet (7) projecting
10 beyond the outlet of the liquid supply duct, the discharge duct leading to a separator (8,14,17,40); feeding water to the liquid supply duct and causing it to swirl at the outlet such that it disturbs the oil and sand particles to cause the oil to be stripped, at least partially, from the
15 particles, and causes the oil and sand particles entrained in the water to travel into the discharge duct and hence to a separator, where the oil, water and solid particles undergo separation.
- 20 2. A method according to claim 1, wherein the separator comprises a single liquid/solid hydrocyclone stage (40), which substantially separates sand and water which report to the underflow (41) from oil and water which report to the overflow (42).
- 25 3. A method according to claim 1, wherein the separator comprises two hydrocyclones stages (8,14) the first of which is a liquid/solid separation hydrocyclone (8), which substantially separates sand, which reports to the
30 underflow (9) from oil and water which report to the overflow (10), and the second of which is a liquid/liquid separation hydrocyclone (14), which substantially separates water which reports to the underflow (15) from oil which reports to the overflow (16).

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4. A method according to any one of the preceding claims, wherein the swirl at the outlet is caused by inclined vanes in the liquid supply duct (5).
- 5 5. A method according to any one of claims 1 to 3, wherein the swirl at the outlet is caused by the liquid supply duct (5) having a tangential inlet into a cylindrical chamber upstream of the liquid supply duct outlet.
- 10 6. A method according to any one of the preceding claims, wherein chemicals are added to the water which is fed to the liquid supply duct (5) of the fluidising unit.
- 15 7. A method according to any one of the preceding claims, wherein the amount of particles in the housing (1) are sensed and the fluidising unit (3) is operated when the amount of particles reaches a threshold value.
- 20 8. An apparatus for carrying out the method according to claim 3, the apparatus comprising a housing (1) having an inlet (2) for oil-coated sand particles, the housing containing a fluidising unit (3) which has a liquid supply duct (5) with an outlet (4) and arranged to be fed with
- 25 water under pressure from outside the housing, and which has a discharge duct (6) within the liquid supply duct and having at its end an inlet (7) projecting beyond the outlet of the liquid supply duct, the discharge duct leading to a separator (8,14) comprising a liquid/solid separation
- 30 hydrocyclone (8), the overflow outlet of which leads to a liquid/liquid separation hydrocyclone (14).
9. An apparatus for carrying out the method according to any one of claims 1 to 7, the apparatus comprising a
- 35 housing (1) having an inlet (2) for oil-coated sand particles, the housing containing a fluidising unit (3) which has a liquid supply duct (5) with an outlet (4) and



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arranged to be fed with water under pressure from outside the housing, and which has a discharge duct (6) within the liquid supply duct and having at its end an inlet (7) projecting beyond the outlet of the liquid supply duct, the
5 discharge duct leading to a separator (40); and a three phase separator (26), to which an overflow (23) from the housing leads.

10. An apparatus according to claim 9, wherein water from
10 the three phase separator (26) is supplied to the liquid supply duct (5) of the fluidising unit (3).

11. An apparatus according to claim 9 or claim 10, wherein the inlet (2) for oil-coated sand particles leads to a
15 cyclonic separator (50,62), the underflow (54,65) of which discharges sand with some associated fluids to a lower portion of the housing (1), and the overflow (51,64) of which discharges oil and water, substantially free of sand, to an upper part of the housing.

20

12. An apparatus according to any one of the claims 8 to 11, wherein the gap between the liquid supply duct (5) and the discharge duct (6) is closable when the fluidising unit (3) is not in use.

25

13. An apparatus according to any one of claims 8 to 12, wherein a jet pump is provided to boost the pressure in the discharge duct (6).

30 14. A separator for separating solid particles from a mixture containing solid particles and a fluid component, the separator comprising a housing (1) having an inlet (2) for the mixture and a separated fluid outlet (23) associated with an upper part of the housing; the inlet for
35 the mixture leading to a cyclonic separator (50,62) such that the mixture is caused to swirl in the cyclonic separator, the cyclonic separator having an overflow



(51,64) for the discharge of fluids to an upper part of the housing, and an underflow (54,65) for the discharge of solid particles and some fluid to a lower part of the housing; and, associated with the lower part of the housing, a fluidising unit (3) which has a liquid supply duct (5) with an outlet (4) and arranged to be fed with liquid under pressure from outside the housing, and which has a discharge duct (6) within the liquid supply duct and having at its end an inlet (7) projecting beyond the outlet of the liquid supply duct.

15. A separator according to claim 14, wherein a plurality of baffles (55,56) are provided in the housing (1) to provide a tortuous path to the upper part of the housing for any fluid discharged from the underflow (54) of the cyclonic separator (50), and which deter any solid particles discharged from the underflow of the cyclonic separator from reaching the upper part of the housing.

20 16. A separator according to claim 14 or claim 15, wherein a gas overflow outlet (52) is provided on the axis of the cyclonic separator (50).

25 17. A separator according to claim 14, wherein the housing (1) is a pressure vessel; the cyclonic separator is at least one hydrocyclone (62), the underflow outlet or outlets (65) of which discharge(s) into a closed underflow chamber (61) of the pressure vessel, in which chamber the fluidising unit (3) is provided.

30 18. A separator according to claim 17, wherein there are a plurality of hydrocyclones (62), and the production fluid inlet (2) for the mixture opens into an inlet chamber (57) and the overflow outlets (64) of the hydrocyclones (62) open into an overflow chamber (60), the inlet and overflow chambers being sealed from one another and from the underflow chamber (61).

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19. A separator according to claim 17 or claim 18, wherein an upper part of the underflow chamber (61) is connected to an overflow outlet (69) from the vessel (1) in order that any gas or oil carried through the hydrocyclone underflow (65) into the underflow chamber (61) flows to and is entrained by the fluids leaving the separated fluid outlet (23).

20. A separator according to any one of claims 17 to 19, wherein the supply duct (5) of the fluidising unit (3) is connected to the production fluid inlet (2) so that a side stream of the mixture drives the fluidising unit.

21. A separator according to any one of claims 14 to 20, wherein the liquid leaving the liquid supply (5) duct is caused to swirl.

22. A separator according to claim 21, wherein the swirl is caused by inclined vanes in the liquid supply duct (5).

23. A separator according to claim 21, wherein the swirl is caused by the liquid supply duct (5) having a tangential inlet into a cylindrical chamber upstream of the liquid supply duct outlet.

24. A separator according to any one of claims 14 to 23, wherein chemicals are added to the liquid which is fed to the liquid supply duct (5) of the fluidising unit (3).

25. A separator according to any one of claims 14 to 24, wherein a sensor is provided to sense the amount of particles in the housing (1), whereby the fluidising unit (3) is operated when the amount of particles reaches a threshold value.

26. A separator according to any one of claims 14 to 25, wherein the gap between the liquid supply duct (5) and the

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discharge duct (6) is closable when the fluidising unit (3) is not in use.

27. A separator according to any one of claims 14 to 26,
5 wherein a jet pump is provided to boost the pressure in the discharge duct (6).

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