

Combined degassing and flotation tank.

Field of the invention

The present invention relates to separation of a
5 mixture comprising water, a with water not miscible
fluid having a lower density than water and a gas
into these constituents.

In particular the present invention relates to a
combined degassing and flotation tank, which is
10 particular, suited for use in separation processes
where a water phase containing oil and gas is
separated into these constituents.

The invention, is applicable within a broad range
of industries comprising the petroleum industry,
15 including oil exploration and production, refining,
transport, storage, cleaning of tanks and/or
equipment etc.

Background for the invention

20 In the oil industry the production of crude oil
involves pumping a mixture of oil, gas and water from
subterranean reservoirs. At the well-head a initial
separation usually takes place, and the crude oil
still containing some gas and water is treated in one
25 or more separators to remove more water and gas
before the crude oil is ready for refining.

At offshore oil production the water phase
coming from the separation at the well-head or
subsequent separators is usually discharged into the
30 sea after a cleansing that involves the partial
removal of gas, oil, chemicals and other impurities.
Today this cleansing is accomplished using large

equipment such as oil/gas separators, flotation tanks, hydro cyclones and degassing tanks occupying a substantial space at the production platforms.

With ageing of the oil fields one often finds
5 that the volume of water accompanying the oil becomes much larger and consequently the capacity for water treatment often needs to be increased to treat the increasing amounts of water.

Further, there is a general concern of the
10 pollution caused by oil production at sea, particular when the oil production takes place in areas that are considered as environmentally fragile, such as arctic areas or fishing areas. In the oil industry there is a fear that a demand for a significant lower limit
15 for the outlet of oil would turn the oil production from a number of the known reservoirs uneconomical if one has to rely on the equipment used at present. Thus great efforts have been made by industry and authorities to find ways to reduce the outlet of oil
20 during oil production at affordable prices.

On oil production platforms intended for
operation at sea, very limited space is usually available. Therefore there are very strict constraints on the space available for installation
25 of new equipment that may be needed in order to handle increasing amounts of water, in particular if one should honour the rising concerns for the environment and reduce the pollution. An even stricter constraint on space may be encountered if
30 one considers the establishment of an oil production at the sea bed level.

In the prior art a number of oil-gas-water

separators are known. In US 4,424,068 a separator and a method for separating a mixture of oil, gas and water, such as may be received from an oil-well is described. The separator is in the form of a vessel
5 divided into separation chambers and provided with a number of baffles and a dynamic separator where the incoming mixture changes direction several times. Despite that the separator have been known for several years it seems not to have been widely used.
10 Further as the separator comprises several chambers and many parts the maintenance will be time consuming which may lead to costly stop of oil production.

US 4,364,833 describes a separator comprising one sector containing numerous plates arranged
15 horizontally and parallel in order to confer coalescence of small oil drops to larger oil drops, and a second sector containing numerous plates arranged vertically and parallel in order to let the formed larger oil drops rise to the top where they
20 form an oil layer which is collected. As the separator contains a number of narrow passages between the parallel plates these passages are susceptible for clogging by solids contained in the incoming flow, which may lead to stop for cleaning.

25 US 3,797,203 describes a separator containing a number of conically formed screens on the surface of which small oil droplets coalesce to larger oil drops which rise to the top of the separator where they can be collected as an oil phase.

30 WO 99/20873 describes a sand trap that may be placed on an oil well in order to remove heavier particles such as sand before further processing of

the crude oil. The device has a mouth towards a relatively narrow part of a tank with a spatial connection towards a relatively widened part of the tank where sand and heavy particles precipitate.

Despite the number of known oil-gas-water separators there is still a need for an improved oil-gas-water separator with a better separation of the phases, which do not need large spaces, which can be continuous operated with low requirement for maintenance and which can be manufactured and operated at moderate price.

Brief description of the invention

According to an aspect of the present invention, there is provided a combined degassing and flotation tank comprising an essentially cylindrical vertical tank, a tangentially arranged inlet, at least one outlet for gas and oil placed in the upper part of the tank, an outlet for water placed in the lower part of the tank, and an inner concentric cylindrical wall forming a flotation and degassing zone between said inner concentric wall and the wall of the tank in the upper part of the tank.

It has turned out that the example combined degassing and flotation tank may perform the desired separation of an oil/gas phase from a water-phase with a surprisingly high efficiency. In use for water treatment in oil production remaining oil and gas may be removed from the outgoing water phase providing an effluent with a very low content of hydrocarbons simultaneously with

the removal of sand and other particulate materials. Further, as the throughput of the tank is very high the space requirement is very modest in relation to the amount of treated water.

In one preferred embodiment the inner concentric cylindrical wall is formed as an inner cylinder placed in the upper part of the tank leaving an open space between said cylinder and the top of the tank, and further comprising an inlet guide vane placed between the tank and the inner cylinder leaving an open space between the inner cylinder and the inlet guide vane, and means for establishing calm streaming around the outlet for water.

In another preferred embodiment the combined degassing and flotation tank comprises an essentially cylindrical vertical tank, a tangentially arranged inlet, an outlet for gas and oil placed in the upper part of the tank, an outlet for water placed essentially in the centre of the bottom, and an essentially concentrically arranged vertical first baffle extending from the top of the tank leaving a passage for water in the lower part of the tank and a passage for gas in the upper part of the tank and an essentially concentric, cylindrical vertical inner baffle of a smaller diameter than the first baffle and extending from the bottom of the tank leaving a passage in the top portion of the tank.

In another preferred embodiment a filtration unit, such as an unit of the adsorption filter type, is connected to the outlet of the combined degassing

and flotation tank, which embodiment leads to a very efficient and high removal of hydrocarbons from the water.

The combined degassing and flotation tank may be particularly suited for treating the water phase originating from the well-head or from subsequent separators before said water phase is discharged to the sea at offshore oil production plants.

Thus, the use of the combined degassing and flotation tank in oil production forms another preferred aspect of the invention.

Brief description of the drawings

Fig 1. is a schematic section through a combined degassing and flotation tank according to the invention,

Fig 2. is a schematic section through a combined degassing and flotation tank according to the invention provided with a centrally placed screen (7) and an outlet for sludge (8), showing the flow in the tank,

Fig 3. is a schematic section through a combined degassing and flotation tank according to the invention where an inner cylinder (10) is placed essentially in the upper part of the tank, leaving an open space between the cylinder and the top of the tank, and extending approximately $\frac{2}{3}$ down into the tank. The tank is further provided with an inlet guide vane (11) and a horizontal circular plate (12) placed in the lower part of the tank, leaving an open space between the plate and the wall of the tank.

Fig 4. is a graph belonging to the experiment indicated in the example showing the efficiency of the combined degassing and flotation tank according to the invention.

5

Detailed description of the invention

The invention is based on the recognition of that flotation of oil drops is significantly facilitated by the simultaneously rising of gas bubbles. Further as the incoming fluid in the tank according to the present invention is conducted into an upwards spiralling movement it is believed that due to the rotation the lighter constituents such as oil drops and gas bubbles will be forced towards the centre of the tank until the inner concentric cylindrical wall is met where oil bubbles and gas bubbles will coalesce and rise due to the lower density than the surrounding water.

Simultaneously sand and other heavy particles that may be entrained by the inlet mixture are forced towards the wall of the tank (1) and fall to the bottom.

Thus according to the invention a flotation and degassing zone is formed in the space between the tank and the inner concentric cylindrical wall in the area from the inlet and up.

The inlet for water is arranged essentially tangentially in order to provide a rotational movement of the water in the tank.

An inlet guide vane (11) may be provided in

connection to the inlet (2) for contaminated water. In this connection an inlet guide vane is a vane arranged on the wall of the tank in order to guide the incoming water into an upward spiralling flow. 5 The inlet guide vane may be short or long extending from 30-330° of the circumference of the tank, preferred 90-300°, more preferred 180-300°, and most preferred around 270°. The inlet guide vane is placed so that an open space is found between the vane (11) 10 and the inner concentric cylindrical wall.

The incoming water is let along the vane until the end of the vane where the water continues in a fan-like pattern, where a part of the water will be "recirculated" in another round along the vane 15 whereas the remaining of the water escapes the circulating. The recirculating fraction is to a large extent determined by the inclination of the vane. By experiments it has been determined that a suitable inclination for the vane is in the range of 5-15°, 20 more preferred 5-10°, and most preferred approximately 7°. At this inclination a suitable recirculated fraction is obtained simultaneously with that the flow is not obstructed in a too high degree.

The term "in connection to the inlet" is 25 intended to mean that the inlet guide vane is arranged so the vane meets the incoming water and guides the incoming water into an upwards spiralling flow.

The outlet for water is placed in the lower part 30 of the tank. It is preferred to place the outlet in a location where the water is streaming calmly in order

to secure that no oil or gas droplets are entrained because of high streaming velocity. Means for establishing calm streaming around the outlet may be provided in order avoid entrainment of oil drops by the rapid water stream. These means may be designed as a horizontal circular plate leaving an open space between the plate and the tank if the outlet is placed essentially in the centre of the bottom, or it may be designed as an downward open ring providing shelter for the outlet if the outlet is placed as one or more outlets in the lower part of the side of the tank.

Depending on the location of the outlet the solid material falling into the bottom of the tank may form a sludge. The deposition of sludge and solid material in the lower part of the tank is disadvantageous as the separating capacity of the tank may be lowered.

If the outlet for water (4) is placed at the lowest point of the tank the falling solid material will mainly be entrained by the water streaming out and thus removed, provided that said tank is not provided with any baffles extending from the bottom. If the outlet for water is placed in a location that allows deposition of sludge it is preferred to provide the tank with an outlet (8) for sludge. The outlet for sludge may be designed for continuous or discontinuous removal of sludge.

One or more outlets for oil and gas may be provided. If more than one outlet for oil and gas is provided one or these outlets may serve as outlet for gas whereas another may serve as outlet for oil.

In connection with the present invention the term "essentially cylindrical" means that the tank is substantially circular and the top and bottom of the tank is plane or curved. In use the tank is placed so
5 that the axis of the cylinder is essentially vertical.

In one embodiment of the invention as shown in fig 3, the combined flotation and degassing tank is provided with an inner cylinder (10) placed in the
10 upper part of the tank leaving an open space between said cylinder and the top of the tank, and further comprising an inlet guide vane (11) placed between the tank (1) and the inner cylinder (10) leaving an open space between the inlet guide vane and the inner
15 cylinder and a horizontal circular plate (12) leaving a passage for water between the plate and the tank.

The inner cylinder (10) is arranged so that passage of oil, gas and water is allowed over the top of the cylinder. The cylinder may extend
20 approximately $1/2' - 3/4$ down into the tank, preferably approximately $2/3$ down the tank.

The ratio of the diameter of the inner cylinder to the tank may be selected between wide limits so that the passage of water is not limited. Preferably
25 said ratio is selected between 0.3 to 0.75, more preferred 0.4-0.6 and most preferred approximately 0.5.

In another embodiment as shown in fig 1. and 2.,
30 a tank (1) is provided with a inlet (2) placed in the lower part of the tank. The inlet (2) is arranged tangentially, which causes the incoming water to

rotate in the tank as illustrated in fig. 2. This rotation creates a centrifugal force which forces the lighter oil drops towards a baffle (5), where they coalesce forming larger drops that eventually rise 5 and are gathered on the top of the liquid between the tank wall and the first baffle (5). Here the oil is removed via an outlet for oil and gas (3).

The water is forced down under the first baffle (5) and up between said first baffle and the outlet 10 (4) and/or the inner baffle (6). The water rises to a certain level, and leaves the tank via the outlet (4).

The baffles are formed essentially as cylinders open in one end and the other end closed by the top 15 or the bottom of the tank.

The first baffle (5) is extending from the top of the tank and may be placed forming a gap between said first baffle (5) and the top of the tank. The first baffle (5) may be formed having a uniform 20 diameter along the total height of the baffle, or it may be formed having a larger diameter in the lower end in order to provide a maximal rotational speed of the liquid in the inlet zone.

The inner baffle (6) is extending from the 25 bottom of the tank and is in one embodiment formed by an extension of the water outlet (4). In the combined degassing and flotation tank according to the invention the inner baffle (6) provides a function as an overflow for the tank determining the water level 30 of the tank. The inner baffle (6) may be formed by the outlet pipe (4) extended to the desired water level.

It is preferred that the water level is predetermined to the same level as the outlet for oil and gas (3) in order to obtain a continuous removal of oil and gas from the tank avoiding accumulations 5 which may lead to reduced capacity for separation.

Between the first baffle (5) and the inner baffle (6) may be inserted further baffles, which preferably are arranged extending alternatively from the top and the bottom of the tank. Such baffles will 10 force the water to make extra travels up and down the tank, which may allow more gas to escape from the water phase.

Each baffle is arranged substantially concentrically with the tank, and should be designed 15 to allow passage of gas in the upper end.

The tank is operated at low pressure in order to let the gas escape the water phase. By low pressure 20 is meant a pressure below 10 bar, such as less than 5 bar or even at atmospheric pressure. By such a low pressure most of the gas will form bubbles in the zone around the inlet (inlet zone) and will as the oil drops be forced to the first baffle (5) where 25 they rise to the top of the tank where the gas leaves via the outlet for oil and gas.

The formation and rise of gas bubbles in the inlet zone further mimics the effects created in traditional flotation tanks where the rise of bubbles 30 of added air leads to an enhancement of the separation of oil from the mixture. Without wishing to be bound by the theory it is believed that bubble

formation and subsequently rise of the formed bubbles in the inlet zone of the combined degassing and flotation tank according to the invention is contributing to the surprisingly high separation efficiency observed.

Due to the beneficial effect of the rising gas bubbles it may even be useful to inject additional gas in the contaminated water before entering into the combined degassing and flotation tank, if the amount of gas in the water is low. It is within the skills of the person skilled in the art to determine the optimal amount of gas in a given contaminated water source and to determine if injection of gas may be advantageous in order to obtain a desired cleansing.

The combined degassing and flotation tank may be provided with a screen to remove fine particles such as asphaltenes, from the effluent. The screen may be placed integrally in the tank as a central cylindrical screen (7) forming a tube around the outlet (4), it may be placed directly mounted to the outlet or as a separate unit outside the tank connected to the outlet.

In one embodiment the inner baffle (6) is formed by the screen (7), in which case the water level is determined by the flow rate through the screen (7).

The screen is made as conventional screens using known materials and designs for screens, as it will be known to the person skilled in the art.

In the case of a combined degassing and flotation tank equipped with a inner baffle (6) and a

central cylindrical screen (7) the tank is conveniently provided with a outlet for removal of material retained by the screen (not shown in the figures) placed in the bottom next to the outlet (4) 5 for the effluent.

The person skilled in the art will appreciate that the combined degassing and flotation tank according to the invention may be used for 2,3 or 4 phase separations where the phases may be selected 10 from: water, oil, gas and solid materials, where at least one of the phases are liquid under the condition of operation.

The dimensions of the combined degassing and flotation tank may be selected depending on the 15 amounts of water intended to be treated. In operation it has been found that the residence time in the tank for a liquid to be treated may be selected between 5 and 300 seconds, preferably 5 - 150 seconds, more preferred 10 - 60 seconds, even more preferred 10-40 20 seconds. A particular preferred residence time is about 20 seconds.

For the combined degassing and flotation tank according to the invention, an efficient flotation volume may be calculated as the volume of the space 25 bounded by the tank (1) and the height of the liquid in the tank. Based on the residence time the capacity of the tank may be calculated e.g. a tank with a efficient flotation volume of 1 m^3 and a residence time for the liquid of 20 seconds has a capacity of 30 180 m^3 per hour.

The ratio of height to diameter of the tank can be selected within wide limits preferably in the

range of 1:1 to 4:1 more preferred from 1:1 to 2:1.

It is within the skills of the person skilled in the art to select materials used for the construction of the tank based on the actual conditions for the intended use, such as the amounts of liquid to be treated, the composition of said liquid, the selected pressure, the temperature of the liquid and the presence of possible corrosive chemicals in any of the phases of the mixture.

10 In the way the combined degassing and flotation tank is formed all surfaces are vertical or at least having a steep inclination or subjected to a rapid flow, which prevents deposit of solids, with the exceptions of the surfaces in the sectors intended
15 for collection of particulate material and sludge, which sectors also preferably have outlets for removal of these materials. Further no narrow passages are present in the tank. Consequently there is no place in the combined degassing and flotation
20 tank according to the invention, which is susceptible to clogging by solid materials. Therefore the combined degassing and flotation tank may be operated continuously without or only with a minimal need for maintenance. The necessary maintenance such as
25 replacement of a cylindrical screen if so provided can easily be performed from the top of the tank, which preferably is constructed to be removable. Thus the combined degassing and flotation tank according to the invention has a remarkable robustness i.e. it
30 can be run for long periods without interruptions, and the few stops that may be required for maintenance can be made short.

The high capacity combined with the small occupied space and the robustness of the combined degassing and flotation tank according to the invention makes it particularly suited for use at offshore oil plants such as oil production platforms. Further it is also well suited for use in oil production in plants located on the sea bed, because at such a location the constraints on space may be even stricter than on traditional oil production platforms and the capacity for maintenance may be lower.

Additives such as flocculants may also be added to the water before entering into the combined degassing and flotation tank according to the invention in order to improve the cleaning efficiency.

In use the combined degassing and flotation tank according to the invention routinely reduces the oil content of an oil/water mixture to 20 mg/l or less starting from several hundred mg/l e.g. 200-800 mg/l.

Full-scale tests (more than 150 m³/h) have shown that the oil content can be lowered from several thousand ppm down to approximately 10 ppm and leaving the water essentially free of gas

In a preferred embodiment the combined degassing and flotation tank is used in combination with a filtration unit, preferably of the adsorption/absorption type, which filtration unit may further reduce the oil content of the effluent water. A particular suited filtration unit for such a combination is the filtration unit disclosed in the European Patent application No. 00610080.4. Starting

from an oil/gas/water mixture containing 400-800 mg hydrocarbons per litre, a reduction of hydrocarbon content to less than 20 mg/l after the combined degassing and flotation tank and a further reduction to 5 mg/l or less after the filtration unit can routinely be obtained, while the high throughput is maintained.

Even though the combined degassing and flotation tank has been described mainly with respect to uses in oil production the invention is not limited to such uses but can be used within a broad range of industries where separations of a liquid mixture of water, a liquid insoluble in water and a gas takes place.

Now the invention is described by an example, which should not be regarded as limiting for the invention.

EXAMPLES

20

Example 1

A combined degassing and flotation tank corresponding to figure 2, having a diameter of 500 mm and a height of 1200 mm and an efficient flotation volume of 125 litre, was tested on water phase effluent from a second step oil separator from a commercial oil production platform. The sample water contained varying amounts of oil and gas in the range equivalent to approximately 50 - 200 mg hydrocarbon per litre. The intake varied between 1.8 and 9.5 m³/h.

The output water contained approximately 20 mg hydrocarbon per litre or less, during most of the experiments less than 20 mg/l. The efficiency of cleaning calculated as percentage hydrocarbon removed was during most of the experiment between 80 and 90 %.

The actual data is shown in fig. 4, which is a graph showing the concentrations of hydrocarbons in the inlet and the effluent stream of the combined degassing and flotation tank measured at regular intervals during the experiment.

Example 2

A combined degassing and flotation tank was designed essentially as depicted in figure 3 having the following dimensions:

	Height	2530 mm
20	Diameter of tank	1130 mm
	Diameter of inner cylinder	appx. 500 mm

And the inner cylinder extending approximately 2/3 down into the tank.

This combined degassing and flotation tank was run in a full scale with an inlet of 150 m³/h.

The plant was operated continuous with out breaks in more that 6 months with an inlet of water contaminated with approximately 200-600 ppm hydrocarbonaceous oil and gas and an outlet

19 MAY 2005

WO 02/41965

PCT/IB01/01878

19

containing 5-10 ppm.

This study confirms the high throughput with high cleansing efficiency essentially without need for 5 intermittently breaks for maintenance.

CLAIMS

1. Combined degassing and flotation tank comprising an essentially cylindrical vertical tank, a tangentially arranged inlet, at least one outlet for gas and oil in the upper part of the tank, an outlet for water placed in the lower part of the tank, and an inner concentric cylindrical wall forming a flotation and degassing zone between said inner concentric wall and the wall of the tank in the upper part of the tank.
2. Combined degassing and flotation tank according to claim 1, where the concentric cylindrical wall is formed as an inner cylinder placed in the upper part of the tank leaving an open space between said cylinder and the top of the tank, and further comprising an inlet guide vane placed between the tank and the inner cylinder leaving an open space between the inner cylinder and the inlet guide vane, and means for establishing calm streaming around the outlet for water.
3. Combined degassing and flotation tank according to claim 2, where the inner cylinder is extending approximately $\frac{2}{3}$ down into the tank.
4. Combined degassing and flotation tank according to claim 2-3, where the inlet guide vane has an upward inclination of approximately 7° .
5. Combined degassing and flotation tank according to any of claim 2-4, where the means for means for establishing calm streaming around the

outlet for water, is shaped as a horizontal circular plate or as a downward open ring around the outlet for water.

6. Combined degassing and flotation tank according to claim 1, comprising an essentially cylindrical vertical tank, a tangentially arranged inlet, an outlet for gas and oil placed in the upper part of the tank, an outlet for water placed essentially in the centre of the bottom, and at least one essentially concentric arranged vertical first baffle extending from the top of the tank leaving a passage for water in the lower part of the tank and a passage for gas in the upper part of the tank, and at least one essentially concentric, cylindrical vertical baffle of smaller diameter than the at least one baffle and extending from the bottom of the tank leaving a passage in the top portion of the tank.

7. Combined degassing and flotation tank according to claim 6, further comprising an inlet guide vane placed in connection with the inlet leaving an open space between the inlet guide vane and the first baffle.

8. Combined degassing and flotation tank according to claim 6-7, wherein the inner baffle forms an extension of the outlet for water.

9. Combined degassing and flotation tank according to claim 6-8, further comprising a screen for retaining particulate material.

10. Combined degassing and flotation tank according to claim 9, wherein the inner baffle is formed by a vertical cylindrical screen.

11. Combined degassing and flotation tank according to claim 9-10, further comprising an outlet for solid material retained by the screen .
12. Combined degassing and flotation tank according to any of claim 1-11, further comprising an outlet for sludge arranged in the lowest part of the tank.
13. Use of a combined degassing and flotation tank according to any of claim 1-12 for separation of hydrocarbonaceous oil and gas from water.
14. Use according to claim 13, where additional gas is injected into the incoming water comprising hydrocarbonaceous oil and gas before entering the tank.
15. Use according to claim 13-14, where a flocculant is injected into the incoming water stream before entering the tank.
16. Use according to claim 13-15, in oil production at sea level or at sea bed level.
17. Use according to claims 13-16, in combination with a filtration unit connected to the outlet for water of said tank.
18. Use according to claim 16 or 17, for treating water from which the main portion of oil and gas has been removed previously by conventional means.