(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
30 July 2020 (30.07.2020)

WIPO | PCT

(10) **International Publication Number**
WO 2020/153850 A2

(51) **International Patent Classification:**
B01D 17/02 (2006.01) ***C02F 9/00*** (2006.01)
B01D 17/00 (2006.01) *C02F 1/36* (2006.01)
B01D 17/12 (2006.01) *C02F 1/40* (2006.01)
B01D 21/00 (2006.01) *C02F 1/44* (2006.01)

(21) **International Application Number:** PCT/NO2020/050009

(22) **International Filing Date:** 22 January 2020 (22.01.2020)

(25) **Filing Language:** Norwegian

(26) **Publication Language:** English

(30) **Priority Data:**
20190082 22 January 2019 (22.01.2019) NO

(71) **Applicant: RENA QUALITY GROUP AS** [NO/NO]; Brevikveien 29c, 4014 Stavanger (NO).

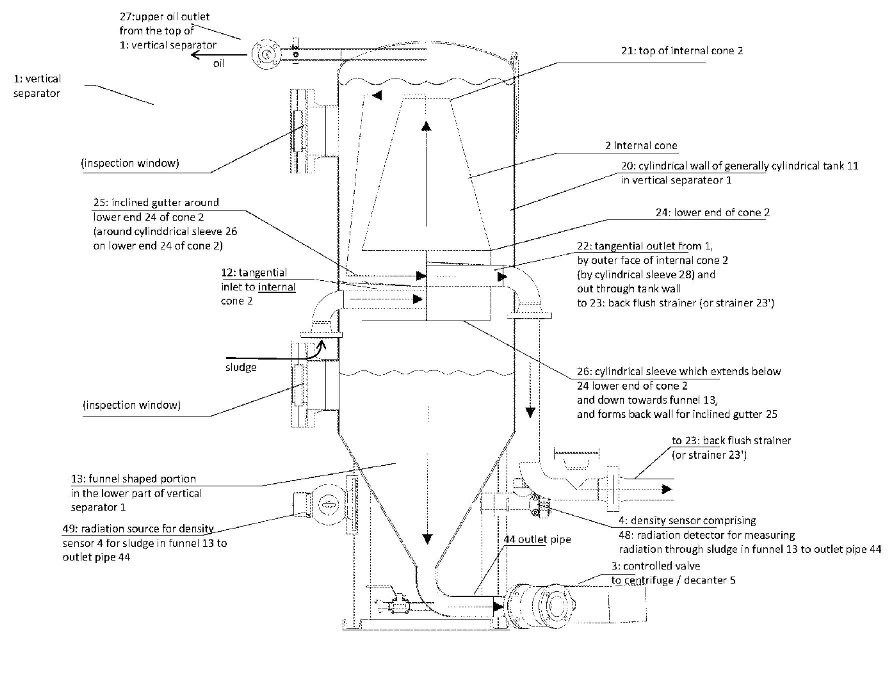
(72) **Inventor: SAMUELSEN, Ørjan Weider**; Halvdan Svartes Gate 11b, 4044 Hafrsfjord (NO).

(74) **Agent: ACAPO AS**; P.O. Box 1880 Nordnes, 5817 Bergen (NO).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,

(54) **Title:** A WATER-OIL-SLUDGE SEPARATION PLANT

Fig. 2



(57) **Abstract:** The invention relates to a water-oil-sludge separation plant comprising: a slop tank (0) for water/oil/sludge, an outlet for slop water to a vertical separator (1) comprising a vertical, substantially cylindrical tank (11), wherein the vertical separator (1) leads to an upper oil outlet (27); a middle, horizontal, tangential outlet (22) for oil-polluted water to a membrane filtration plant (6); and a lower pipe (44) for sludge outlet to a decanter/centrifuge (5); wherein the decanter / centrifuge (5) is arranged -to separate dehydrated solids, and - to lead water treated in the centrifuge back to the vertical separator (1) or the slop tank (0); wherein the membrane filtration plant (6) is arranged - to lead the concentrated retentate back to the vertical separator (1) or to the slop tank (0) or remove from the process; - wherein the permeate comprising cleansed water is let out; wherein the sludge outlet (44) from the vertical separator (1) comprises a control valve (3) controlled by a control unit (41) that, based on a sensor (4) for density of sludge in a lower portion of the vertical

WO 2020/153850 A2

[Continued on next page]

SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

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

Published:
— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

separator (1), continuously adjusts outlet of sludge to the decanter/centrifuge (5).

A water-oil-sludge separation plant

Introduction

Invention relates to a water-oil-sludge separation plant. More specifically, the invention relates to a water-oil-sludge separation plant having a vertical separator that coarsely separates oil in an upper outlet, oil-polluted water in a middle section and heavier sludge in a lower outlet leading to a decanter/centrifuge. The oil-polluted water from the middle section is led into a membrane filtration plant where permeate water is so pollution-free that it may be dumped and the retentate may be separated as separated oil or transported back, directly or indirectly, to the vertical separator. The sludge including oil, water and heavier constituents such as mud, cement residues, cuttings and metal particles is through an automatic control valve transported to a separator/decanter and creates a solid dehydrated matter that may be destroyed, and oil-polluted water or oil and water that each may be transported back to the slop tank in order to eventually be transported through the vertical separator and after that mainly to the membrane filtration plant.

State of the Art

State of the art comprises centrifuge/decanter that centrifuges all material arriving from the slop tank and transports the separated, oil-polluted water to a membrane-based filtration plant. Drawback associated with such a plant is the centrifuge needs to be dimensioned for operation to separate all liquid with the sludge from the slop tank. This is not an efficient solution.

CN107043204 describes a system for processing of oil sludge comprising a control reservoir for mixing and stirring the oil sludge with water in order to obtain an emulsion consisting of water and oil sludge. It comprises a first step, three-phase separator for cold, i.e. at normal temperature, three-phase separation of said emulsion in order to obtain a first step sand, a first step waste water and a first step waste oil. It further comprises a second step, three-phase separator for warm three-phase separation of the waste water of the first step in order to obtain a second step oil sludge sand, a second step waste water, a second step waste oil and an organic gas mixture. It also comprises an oil-water separator for separating the first step waste oil from the second step waste oil in order to obtain separated waste water and mixed sludge waste. In addition, it comprises a sedimentation dam for precipitation caused by flocculation of the second step waste water to obtain a sludge and a supernatant. Finally, it comprises a sintering plant and a sludge incineration plant. According to the system for processing of the oil sludge, two-step, three-phase separation is obtained such that heat is generated by means of incineration, coal briquettes are created and sintered materials as well as a technical system having low emissions of oil sludge.

WO1999/42218 "Jet pump treatment of heavy oil production sand" discloses a plant with a high pressure treatment of sand slurry in order to separate particles in the bottom of a cylindrical tank having a conical bottom section to a jet pump and wherein the plant separates slop oil over a slurry level at approximately 90 % of the tank height. The tank has a conical top at which organic gas is exhausted.

Brief Summary of the Invention

The present invention is defined in the accompanying claim set.

Beneficial embodiments of the invention are defined in the dependent claims.

Advantages of the Invention

A first advantage of the invention is that the vertical separator provided between the slop tank and the membrane separator effects a coarse separation and effectively separates lighter oil to an upper oil outlet. This light oil would otherwise need to pass through the centrifuge and its separation would consume a lot of energy. In contrast to the oil separation process by means of membrane filtration plant, it is much more efficient to separate an oil retentate where a large portion of the oil is separated earlier in the process by means of the vertical separator according to the invention. Another advantage of the invention is that the amount of liquid and solid entering the centrifuge/decanter is significantly less compared to the methods of the prior art since a significant portion of the oil may be collected via top of the vertical separator.

A further advantage of the invention is that the oil-polluted water entering the membrane filtration plant is less polluted and includes significantly fewer particles than the methods of the prior art. Yet another advantage of the invention is that the concentrated retentate, mainly consisting of oil, may be transferred back to the tank via a control valve and further into the vertical, cylindrical tank. As a consequence, there is no need to constantly monitor the amount of retentate and the oil fraction of the concentrated retentate is let out through the outlet at the top of the vertical, cylindrical tank jointly with the oil that is directly separated in the vertical, cylindrical tank.

An advantage of the invention is that anionic polymers in bore liquid that otherwise might clog the membrane may be flocked out using for instance lime $CaOH_2$ and convert these to solids that may be let out via the strainer.

The result is a continuous and efficient process to separate oil-polluted mud and water. Using the present method, old mud, i.e. waste material, may be separated and circulated out of the well in a plugging-and-abandonment operation employing polluted bore liquids with cuttings, cement, spacer fluid, waste and water.

Short Description of the Drawings

The invention is illustrated in the accompanying drawings, wherein:

Fig. 1 is a perspective view of the separation plant with a slop tank, a vertical separator, a membrane filtration plant and a centrifuge/decanter.

Fig. 2 shows a simplified drawing of a vertical separator for use in the system according to the invention. The wall of the cylindrical tank is shown as being transparent.

Fig. 3 is a system drawing corresponding to the drawing of Fig. 1 and including a slop tank, a vertical separator, a strainer, a balance tank, a membrane filtration plant and a centrifuge/decanter. In the embodiment shown in Fig. 3, it is shown a density sensor for sludge accumulating in the lower, funnel-shaped portion of the vertical separator. The sensor comprises a radioactive source for radiating through the funnel-shaped portion and an oppositely arranged radioactive sensor measuring radiation that penetrates while being attenuated depending on the density (and the material composition) of the sludge precipitated in the funnel. The signal captured by the radioactive sensor is sent into a control unit of the control valve that opens so that an even, desired flow from the funnel is achieved and an even inflow of slop from the slop tank to the vertical separator, and an even flow of sludge from the funnel to the decanter/centrifuge.

Figs. 4a-4d shows variants of the embodiment showing density sensors and strainers.

Fig. 4a illustrates an embodiment having an automatic “back flush strainer” for oil-polluted water at the outlet. In this embodiment it is also provided a radioactive source and a density sensor for sludge accumulating in the lower, funnel-shaped portion of the vertical separator.

The sensor comprises a radioactive source for radiating through the funnel-shaped portion and an oppositely arranged radioactive sensor measuring radiation that penetrates while being attenuated depending on the density (and the material composition) of the sludge precipitated in the funnel. This embodiment is also shown in Figs. 2 and 3.

Fig. 4b shows another embodiment with manually operated, double strainers for alternate use, and the density sensor measures Coriolis-based instrument (also measuring flow speed) and providing a signal to the control unit controlling the control valve.

Fig. 4c illustrates another embodiment with a back flush strainer and a Coriolis-based density measurement device and a flow measurement device used to provide a signal for controlling the control valve.

Fig. 4d illustrates another embodiment with a manually operated strainer and a radioactive sensor to provide a signal for controlling the control valve.

Description of the embodiments of the invention

The invention is a water-oil-sludge separation plant comprising a slop tank (0) for water/oil/sludge having an outlet for slop water to a vertical separator (1). The slop water tangentially enters the interior of a vertical bushing (20) underneath an inner cone (2) open in the bottom, wherein the cone tapers upwardly, see Fig. 2.

The vertical separator (1) leads to three outlets:

An upper oil outlet (27) that lets out air and oil that are easily separated in a cyclone separation motion that arises in the vertical inner cone (2), see Fig. 1.

A middle, horizontal tangential outlet (22) for oil-polluted water to a membrane filtration plant (6).

Oil-polluted water is separated via the top of the cone (2) and subsides externally with respect to the cone and enters a lower funnel (13) with a lower pipe (44) for sludge outlet to a decanter/centrifuge (5).

The decanter/centrifuge (5) is arranged to separate the slurry in two components:

Firstly, to separate dehydrated solids that may subsequently be stored or destroyed.

Secondly, to transfer water treated in the centrifuge back to the vertical separator (1) or to the slop tank (0).

The membrane filtration plant (6) is also a part of the invention and is arranged for two main functions:

Firstly, to separate a concentrated retentate and directly remove it from the process, or transport it, directly or indirectly, via the slop tank (0) to the vertical separator (1).
Secondly, wherein the permeate that comprises cleansed water is dumped or let out or recirculated if the need exists.

In accordance with the invention, the separation plant is arranged such that the slop water enters through a vertical cylindrical sleeve-shaped wall (20) in the vertical separator (1) and thereafter tangentially, horizontally into an upwards-tapering cone (2) surrounded by the vertical, cylindrical tank (11) wherein water with oil exits via the top (21) of the cone (2).

Oil and possibly air are let out through an oil outlet (27) at the top of the vertical, substantially cylindrical tank (11). This oil mat be let out/processed/recovered/stored.

Oil-polluted water continues to flow downwards from the top (21), externally with respect to the cone (2), to a tangential outlet (22) at a lower end (24) of the cone (2), and generally to the membrane filtration plant (6).

In accordance with another embodiment of the invention of the separation plant, the cone (2) separates the slurry that subsides in the interior down to a funnel (13) with the pipe (44) for sludge outlet from the bottom of the vertical, substantially cylindrical tank (11).

In accordance with another embodiment of the separation plant, an inclined gutter (25) is provided at the lower end (24) of the cone (2) such that the inclined gutter (25) leads to the tangential outlet (22). In this way, sedimentation of particles present in the water at the lower end of the cone upstream of the outlet (22) may be avoided.

In an embodiment of the separation plant, a cylindrical sleeve (26) is provided, said sleeve extending concentrically from the lower end (24) of the cone (2) and providing a back wall within the inclined gutter (25). This extends downwards to create a channel for the inlet water to the tank such that it doesn't flow into the cone immediately. Heavier fractions and particles and water are led downwards towards the lower, funnel-shaped portion (13) of the tank.

In a two-phase separator embodiment of the invention, the decanter/centrifuge (5) may be arranged to jointly separate water and oil and lead separated oil and water, directly or indirectly, back to the vertical separator (1). In a three-phase separator embodiment of the invention, the decanter/centrifuge (5) is arranged to lead separated oil so that it is recovered and separated water back to the slop tank or the vertical separator.

In one embodiment of the invention, a back flush strainer (23) is provided between the vertical separator (1) and the membrane filtration plant (6), wherein the back flush strainer (23) is provided between the tangential outlet (22) and the membrane filtration plant (6), said back flush strainer (23) being arranged to filter and remove particles and wherein the permeate water that is free from particles and oil-polluted is led to the membrane filtration plant (6). In an embodiment of the invention, a strainer (23') may be used between the vertical separator (1) and the membrane filtration plant (6), wherein a strainer (23) is provided between the tangential outlet (22) and the membrane filtration plant (6), said strainer (23) being arranged to filter and remove particles, and wherein the permeate water that is still oil-polluted, but free from particles is transported back to the membrane filtration plant (6). Such embodiments are shown in Figs. 4b and 4d wherein the back one is hidden by the front one. In these drawings, it is provided two strainers (23') connected in parallel wherein it is possible to alternate between letting the outlet (22) lead to the one strainer (23') for normal operation with outlet to the membrane filtration plant (6), while the other strainer (23') is shut off and emptied from particles, or the other way around.

In one embodiment of the invention, the back flush strainer (23) is arranged to transport the separated, heavy particles back to the slop tank (1) and further to the vertical separator (1) and preferably end up in the lower, funnel-shaped portion (13) and eventually in the sludge outlet (44) for further separation in the decanter/centrifuge (5).

In one embodiment of the invention, a balance tank (28) is provided between the tangential outlet (22) and the membrane filtration plant (6), wherein the balance tank (28) is arranged to ensure that the membrane filtration plant (6) receives sufficient amounts of feed water, and possibly even to dose detergent when "Cleaning-In-Place" is performed. The oil-polluted water is led via a feed pump (29) to the membrane filtration plant (6), see Figs. 1 and 3. When the level in the balance tank (28), said level being controlled by a level sensor and a control valve, drops to a low level, the membrane filtration plant (6) is controlled so that it recirculates polluted and clean water back into the tank such that the level in the balance tank (28) doesn't drop even more and the pumps experience problems and suck in air into the membrane filtration plant (6). The recirculation is actually an important property of the plant as it is not desirable to stop the recirculation pumps (62) of the membrane filtration plant (6) every time the flow out of the tangential outlet (22) of the vertical separator (1) must be stopped in consequence of high density measured by the density sensor (4, 49, 48) in the funnel (13), the bottom of the vertical separator (1).

In an advantageous embodiment of the invention, the membrane filtration plant (6) is a tangential membrane filtration plant with a circulation pump (62), i.e. not a so-called "dead-end" membrane filtration plant. The water with the retentate is circulated and the permeate is transported tangentially out through the membrane. In the preferred embodiment, the membrane comprises pipes made of ceramics.

In an embodiment of the invention, the tangential membrane filtration plant (6) is arranged to lead the permeate water to be let out or to be dumped in a body of water, and return the concentrated retentate back to the slop tank (0) and to the tangential intake (12) for continuous separation occurring in the vertical separator (1), see Fig. 3, wherein the separated oil is led back for new processing wherein oil may be let out via outlet (27) in the top of the vertical separator or otherwise be led back into the circuit of the membrane filtration plant (6). In a situation where a risk of the liquid in the balance tank having too low level, the permeate water may be temporarily led back into the balance tank.

The sensor (4) for density of sludge may be of different types. In one embodiment, the sensor for density of sludge is a radioactive, absorption-based sensor comprising:

- a radiation source (49) provided on a first outer face of the funnel (13) for radiating a liquid, possibly including slurry, in the funnel (13),
- a radiation detector (48) provided on the opposite face of the funnel (13) and arranged to receive beams from the radiation source (49);
- wherein the degree of absorption of the radiation indicates a calibrated measurement of the quantum of slurry present in the funnel (13);
- wherein the control unit (41), based on the measurement of the quantum of slurry present in the funnel (13) opens the control valve (3). The control unit (41) holds the control valve (3) open until the quantum of slurry present in the funnel is below a

given limit value. The control unit (41) may control the control valve (3) to open fully or partially depending on the quantum present and the capacity downstream.

In one embodiment of the invention, the density sensor (4) comprises a mass-flow meter measuring density and flow towards the decanter/centrifuge (5). Such a density sensor may be based on ultrasound measurement of density and flow. The flow may be measured by means of an ultrasound-Doppler instrument. In another embodiment, the density sensor (4) may be a density sensor of the Coriolis type as shown in Figs. 4b and 4c. In one embodiment of the invention, the Coriolis-based density sensor will also be arranged to provide signal regarding mass flow through the outlet (44). The density signal from the density sensor (4) or the Coriolis-based density sensor (4') and preferably also the signal regarding mass flow may be used as input to the control unit controlling the control valve (3) at the outlet (44) such that the level of sludge and its density in the funnel-shaped portion are maintained at an acceptable level such that a continuous process may be established.

In another embodiment, the plant is programmed to run in the following way: the density sensor/mass flow meter (4, 4') and the control valve (3) are connected to the sludge outlet (44) of the vertical separator (1). The control unit (41) is programmed so that a constant flow is flowing through the outlet (44) of the vertical separator (1) towards the centrifuge/decanter (5). This flow is determined based on the capacity of the decanter. The density sensor/mass flow meter (4, 4') will, in addition to the constant flow, also measure the density/weight of the slurry/flowing mass. When this density becomes higher than desirable, the control valve (3) is controlled to let out equal amount or more liquid flow than before, while the horizontal outlet (22) of the vertical separator towards the balance tank is closed by means of a valve (46) such that this heavy slurry/liquid doesn't spread out throughout the cone and towards the membrane filtration plant (6) where it is undesirable to have any slurry.

In one embodiment of the invention, the control unit (41), in addition to controlling the control valve (3) for slurry from the funnel (13), also controls another control valve (46) for complete or partial closure of the tangential outlet (22) to the strainer (23) while the control valve (3) is completely or partially open, in order to avoid imbalance in the vertical separator (1) or lack of liquid in the balance tank (28) while the funnel (13) is being drained from sludge. The valve (46) is closed to prevent heavy liquid/sludge from spreading upwards in the cone and the membrane system. It may occur a situation where non-polluted bore liquid is started to be pumped into the vertical separator (1) and that the flow towards the membrane system is no longer desirable for a certain time period. The flow towards the balance tank (28) will then be reduced and the membrane filtration plant (6) will be circulated into this tank such that said tank is at least partially full and the circulation pumps need not be stopped in this phase.

A simplified embodiment of the invention: under certain circumstances, the system may operate without centrifuge/decanter. The sludge is instead let out of the outlet pipe (44) and led to a separate, smaller tank for heavier slurry, or to a separate separator, for instance a filter press. The invention is then a water-oil-sludge separation plant characterized by following features:

- a slop tank (0) for water/oil/sludge having an outlet for slop water to a vertical separator (1);
- the vertical separator (1) leads to three outlets:

    - an upper oil outlet (27) that lets out air and oil that are easily separated in a cyclone separation motion that arises in the vertical inner cone (2), see Fig. 1;

    - a middle, horizontal tangential outlet (22) for oil-polluted water to a membrane filtration plant (6);

    - a lower pipe (44) for sludge outlet to a separate tank or process for separate treatment of the sludge;

- a membrane filtration plant (6) is also a part of the invention and is arranged for two main functions:

Firstly, to separate a concentrated retentate and directly remove it from the process, or transport it, directly or indirectly, via the slop tank (0) to the vertical separator (1).
Secondly, wherein the permeate comprises cleansed water that is dumped or let out or recirculated if the need exists.

In accordance with the invention, the lower pipe (44) for sludge outlet from the vertical separator (1) comprises a control valve (3) controlled by a control unit (41) that, based on a sensor (4, 4') for density of sludge in a lower portion of the vertical separator (1), continuously adjusts outlet of sludge to the decanter/centrifuge (5).
'

Claims

1. A water-oil-sludge separation plant comprising:

- a slop tank (0) for water/oil/sludge,
- an outlet for slop water to a vertical separator (1) comprising a vertical, substantially cylindrical tank (11), wherein the vertical separator (1) leads to
- an upper oil outlet (27);
- a middle, horizontal, tangential outlet (22) for oil-polluted water to a membrane filtration plant (6); and
- a lower pipe (44) for sludge outlet to a decanter/centrifuge (5); wherein the decanter/centrifuge (5) is arranged
  - to separate dehydrated solids, and
  - to lead water treated in the centrifuge back to the vertical separator (1) or the slop tank (0);
- wherein the membrane filtration plant (6) is arranged

  - to lead the concentrated retentate back to the vertical separator (1) or to the slop tank (0) or remove from the process;

  - wherein the permeate comprising cleansed water is let out;

- wherein the sludge outlet (44) from the vertical separator (1) comprises a control valve (3) controlled by a control unit (41) that, based on a sensor (4) for density of sludge in a lower portion of the vertical separator (1), continuously adjusts outlet of sludge to the decanter/centrifuge (5),

characterized in that

- an upwards-tapering conical frustum (2) provided in the interior of the vertical, substantially cylindrical tank (11), wherein the slop water enters through a wall (20) of the vertical separator (1) and subsequently through a tangential intake (12), horizontally in the interior of the upwards-tapering conical frustum (2) surrounded by the vertical, substantially cylindrical tank (11), and wherein water with oil exits via top (21) of the conical frustum (2) and

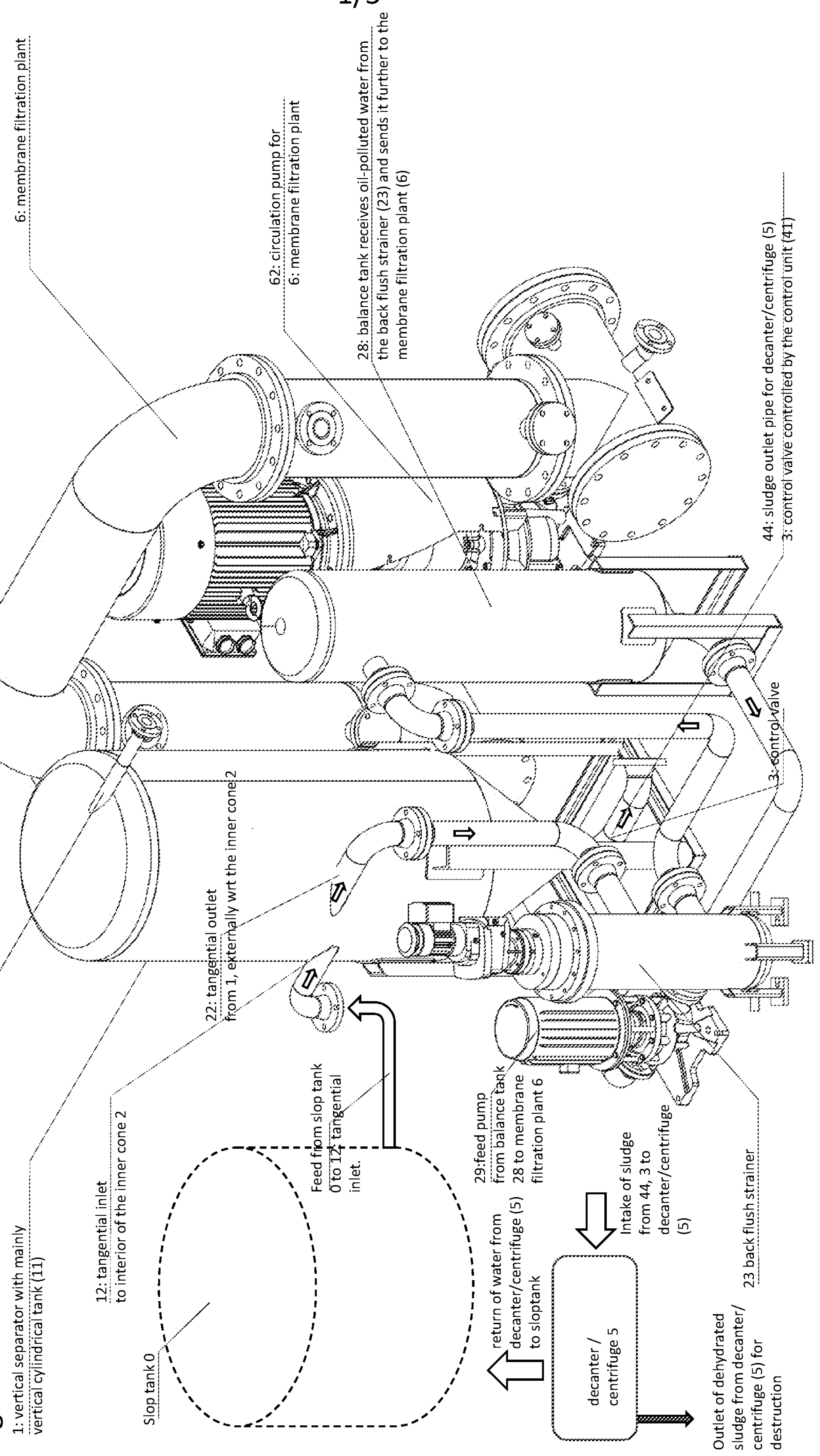
  - wherein oil and possibly air are let out through an oil outlet (27) at the top of the vertical, substantially cylindrical tank (11),

  - and wherein oil-polluted water continues to flow downwards, externally with respect to the conical frustum (2), to a tangential outlet (22) at a lower end (24) of the conical frustum (2), to the membrane filtration plant (6).

2. A separation plant in accordance with claim 1, wherein the conical frustum (2) separates the slurry that subsides in the interior down to a funnel (13) with the pipe (44) for sludge outlet from the bottom of the vertical, substantially cylindrical tank (11).
3. A separation plant in accordance with any of the preceding claims, wherein an inclined gutter (25) is provided at the lower end (24) of the conical frustum (2), wherein the inclined gutter (25) leads to the tangential outlet (22).
4. A separation plant in accordance with claim 3, wherein a cylindrical sleeve (26) is provided, said sleeve extending concentrically from the lower end (24) of the conical frustum (2) and providing a back wall within the inclined gutter (25).
5. A separation plant in accordance with any of the preceding claims, wherein the decanter/centrifuge (5) is a three-phase separator arranged to lead separated oil so that it is let out/recovered.
6. A separation plant in accordance with any of the preceding claims, wherein the decanter/centrifuge (5) is a two-phase separator arranged to lead separated oil and water back to the slop tank or to the vertical separator (1).
7. A separation plant in accordance with any of the preceding claims, wherein a back flush strainer (23) is provided between the vertical separator (1) and the membrane filtration plant (6), wherein the back flush strainer (23) is provided between the tangential outlet (22) and the membrane filtration plant (6), said back flush strainer (23) being arranged to filter and remove particles and wherein the permeate water that is free from particles and oil-polluted is led to the membrane filtration plant (6).
8. A separation plant in accordance with any of the preceding claims, wherein the back flush strainer (23) is arranged to transport the separated, heavy particles back to the slop tank (1) for further treatment in the vertical separator (1) for possible further separation in the decanter/centrifuge (5).
9. A separation plant in accordance with any of the preceding claims, wherein a balance tank (28) is provided between the tangential outlet (22) and the membrane filtration plant (6), wherein the balance tank (28) is arranged to ensure that the membrane filtration plant (6) receives sufficient amounts of feed water, and weakly oil-polluted water is led to a feed pump (29) and further to the membrane filtration plant (6).
10. A separation plant in accordance with claim 9, wherein the membrane filtration plant (6) is a tangential membrane filtration plant with a circulation pump (62).
11. A separation plant in accordance with any of the preceding claims, wherein the tangential membrane filtration plant (6) is arranged to lead the permeate water to be let out or to be dumped in a body of water, and return the concentrated retentate back to the slop tank (0)

and to the tangential intake (12) in the vertical separator back for new processing wherein oil may be let out via outlet (27) or, possibly, be temporarily led back into the balance tank.

12. A separation plant in accordance with any of the preceding claims, wherein the sensor (4) for density of sludge is a radioactive, absorption-based sensor comprising:
    - a radiation source (49) provided on a first outer face of the funnel (13) for radiating a liquid, possibly including slurry, in the funnel (13),
    - a radiation detector (48) provided on the opposite face of the funnel (13) and arranged to receive beams from the radiation source (49);
    - wherein the degree of absorption of the radiation indicates a calibrated measurement of the quantum of slurry present in the funnel (13);
    - wherein the control unit (41), based on the measurement of the quantum of slurry present in the funnel (13), opens the control valve (3) until the quantum of slurry present in the funnel is below a given limit value.
13. A separation plant in accordance with any of the preceding claims, wherein the control unit (41), in addition to controlling the control valve (3) for slurry from the funnel (13), also controls another control valve (46) for complete or partial closure of the tangential outlet (22) to the strainer (23) while the control valve (3) is completely or partially open, in order to avoid imbalance in the vertical separator (1) or lack of liquid in the balance tank (28) while the funnel (13) is being drained from sludge.



27: upper oil outlet from top of the 1: vertical separator
6: membrane filtration plant
62: circulation pump for
6: membrane filtration plant
28: balance tank receives oil-polluted water from the back flush strainer (23) and sends it further to the membrane filtration plant (6)
44: sludge outlet pipe for decanter/centrifuge (5)
3: control valve controlled by the control unit (41)
3: control valve
1: vertical separator with mainly vertical cylindrical tank (11)
12: tangential inlet to interior of the inner cone 2
22: tangential outlet from 1, externally wrt the inner cone 2
Slop tank 0
Feed from slop tank 0 to 12: tangential inlet.
29:feed pump from balance tank 28 to membrane filtration plant 6
return of water from decanter/centrifuge (5) to sloptank
decanter / centrifuge 5
Intake of sludge from 44, 3 to decanter/centrifuge (5)
23 back flush strainer
Outlet of dehydrated sludge from decanter/ centrifuge (5) for destruction

Fig. 1

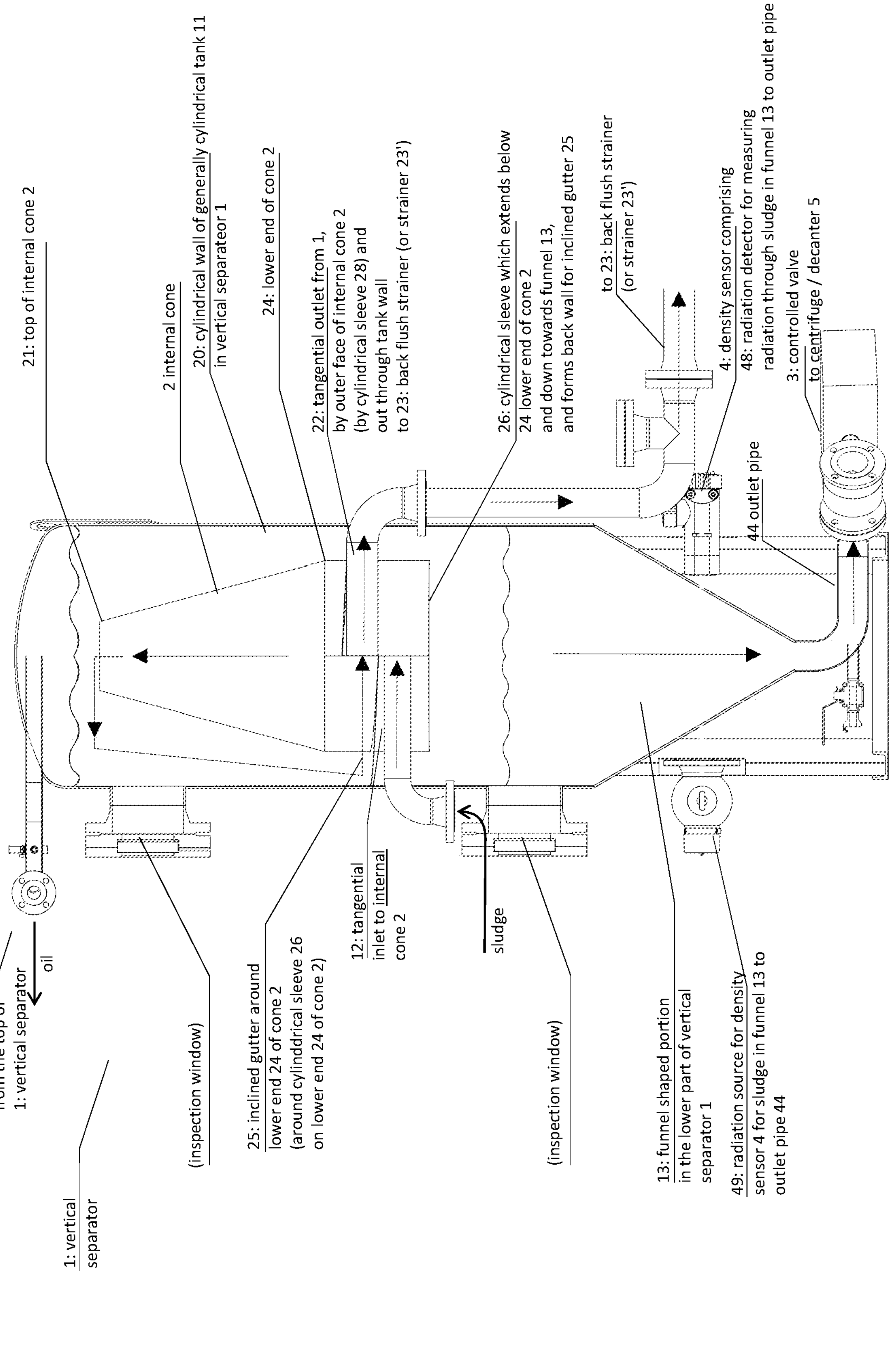
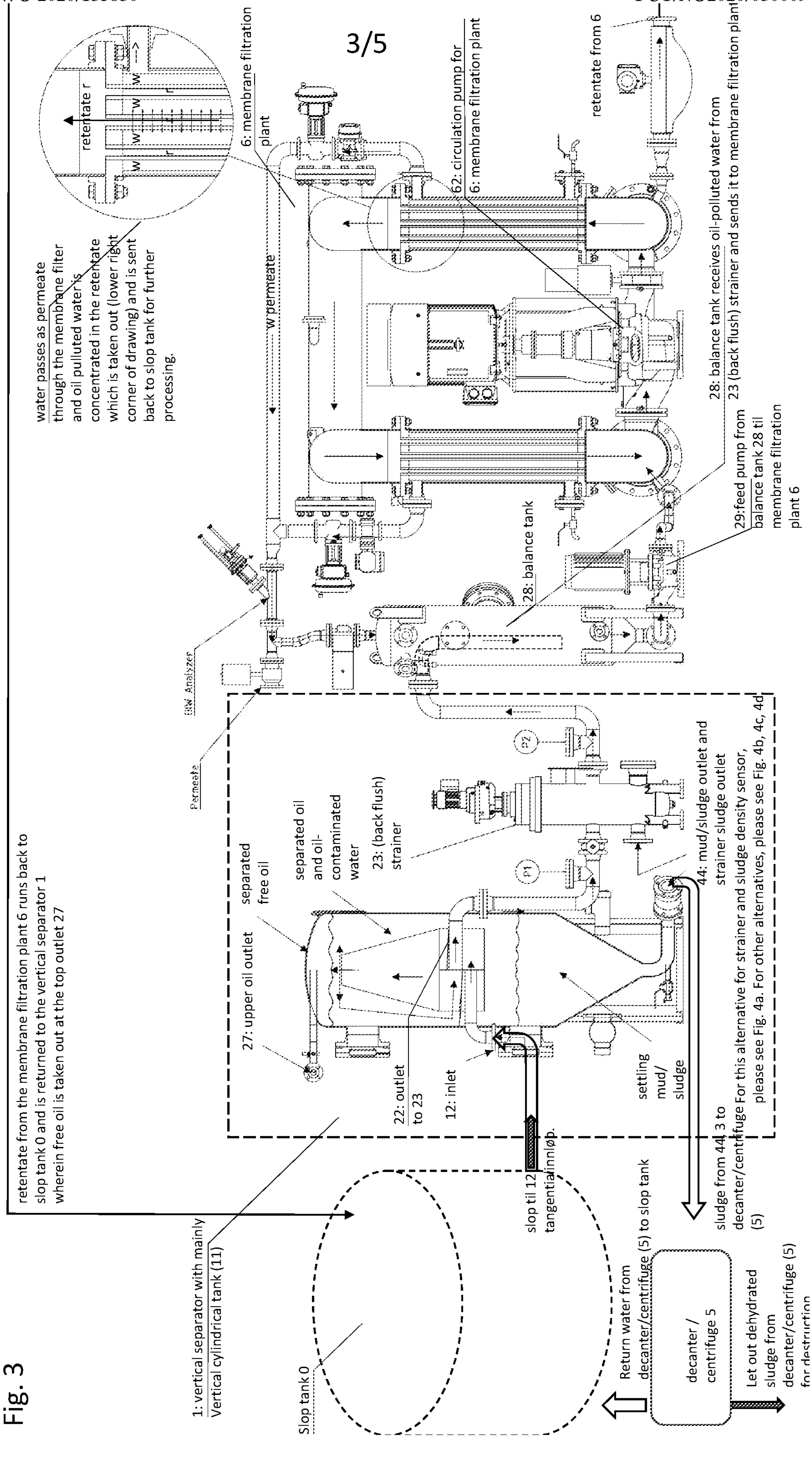

21: top of internal cone 2
2 internal cone
20: cylindrical wall of generally cylindrical tank 11
in vertical separateor 1
24: lower end of cone 2
22: tangential outlet from 1,
by outer face of internal cone 2
(by cylindrical sleeve 28) and
out through tank wall
to 23: back flush strainer (or strainer 23')
26: cylindrical sleeve which extends below
24 lower end of cone 2
and down towards funnel 13,
and forms back wall for inclined gutter 25
to 23: back flush strainer
(or strainer 23')
4: density sensor comprising
48: radiation detector for measuring
radiation through sludge in funnel 13 to outlet pipe 44
3: controlled valve
to centrifuge / decanter 5
44 outlet pipe
27:upper oil outlet
from the top of
1: vertical separator
oil
1: vertical
separator
(inspection window)
25: inclined gutter around
lower end 24 of cone 2
(around cylinddrical sleeve 26
on lower end 24 of cone 2)
12: tangential
inlet to internal
cone 2
sludge
(inspection window)
13: funnel shaped portion
in the lower part of vertical
separator 1
49: radiation source for density
sensor 4 for sludge in funnel 13 to
outlet pipe 44

Fig. 2

Fig. 3



retentate from the membrane filtration plant 6 runs back to slop tank 0 and is returned to the vertical separator 1 wherein free oil is taken out at the top outlet 27
water passes as permeate through the membrane filter and oil pulluted water is concentrated in the retentate which is taken out (lower right corner of drawing) and is sent back to slop tank for further processing.
retentate r
w
r
6: membrane filtration plant
62: circulation pump for 6: membrane filtration plant
retentate from 6
w permeate
28: balance tank receives oil-polluted water from 23 (back flush) strainer and sends it to membrane filtration plant
29:feed pump from balance tank 28 til membrane filtration plant 6
28: balance tank
BW Analyzer
Permeate
P2
P1
23: (back flush) strainer
separated free oil
separated oil and oil-contaminated water
27: upper oil outlet
22: outlet to 23
12: inlet
settling mud/ sludge
44: mud/sludge outlet and strainer sludge outlet
For this alternative for strainer and sludge density sensor, please see Fig. 4a. For other alternatives, please see Fig. 4b, 4c, 4d
sludge from 44, 3 to decanter/centrifuge (5)
1: vertical separator with mainly Vertical cylindrical tank (11)
slop til 12 tangential innløp.
Return water from decanter/centrifuge (5) to slop tank
Slop tank 0
decanter / centrifuge 5
Let out dehydrated sludge from decanter/centrifuge (5) for destruction

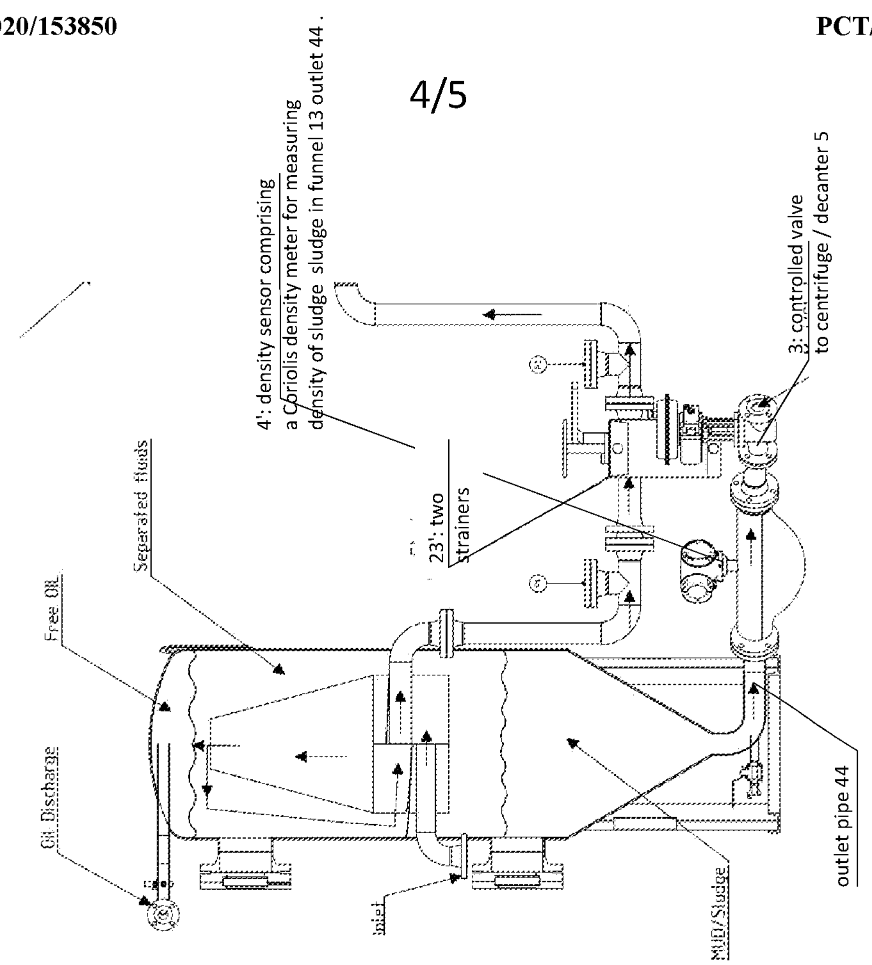


Fig. 4b: Embodiment with (manual) strainer and Coriolis density and flow meter controlling valve 3

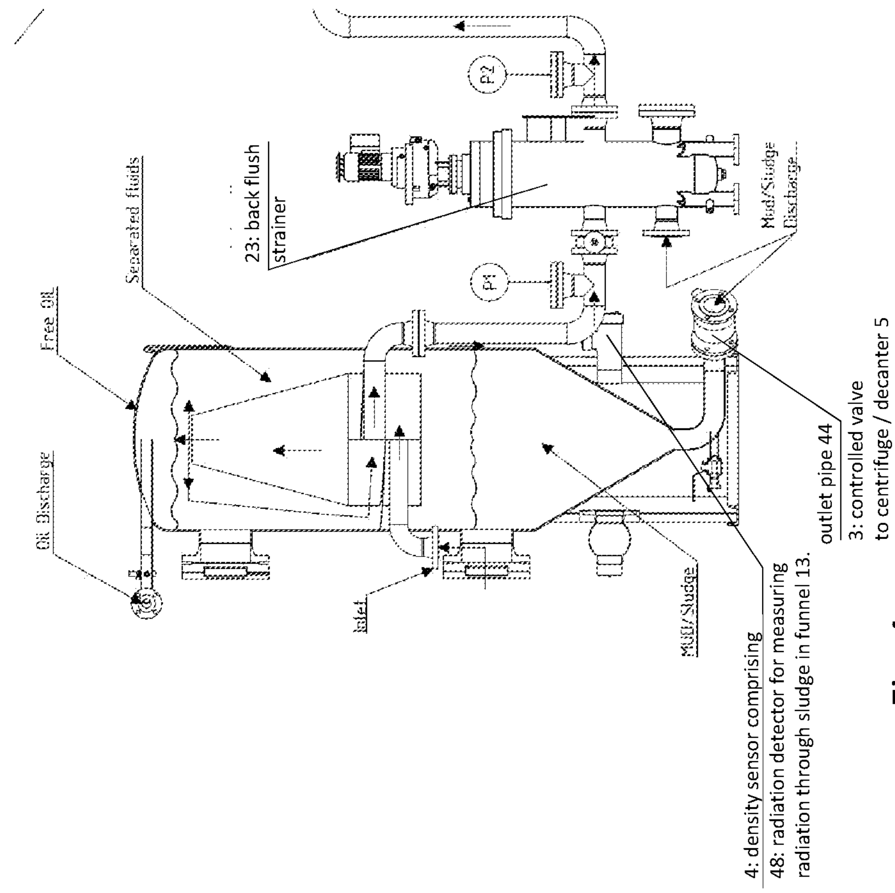


Fig. 4a: Embodiment with back flush strainer and radioactive sensor control for valve 3,
ref. (Figs. 2 and 3)

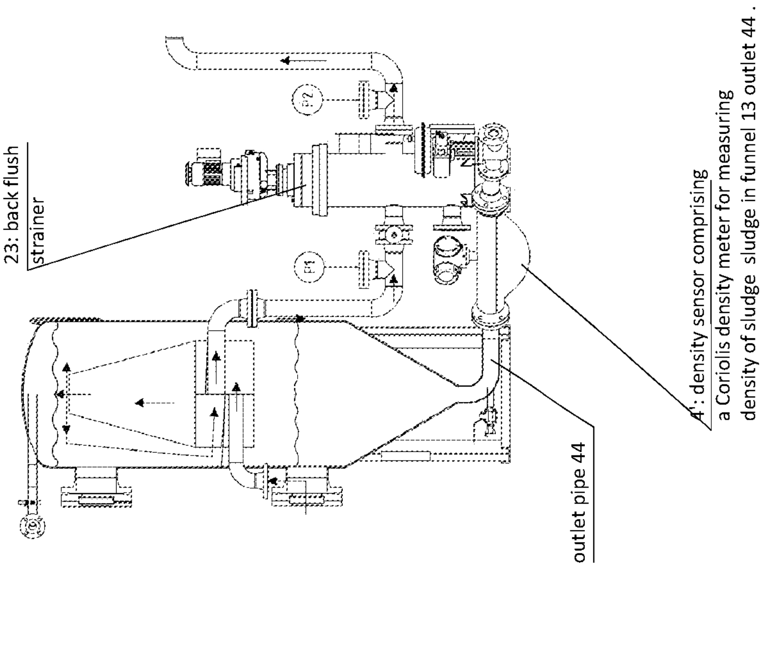


Fig. 4c: Embodiment with back flush strainer and Coriolis density and flow meter controlling valve 3

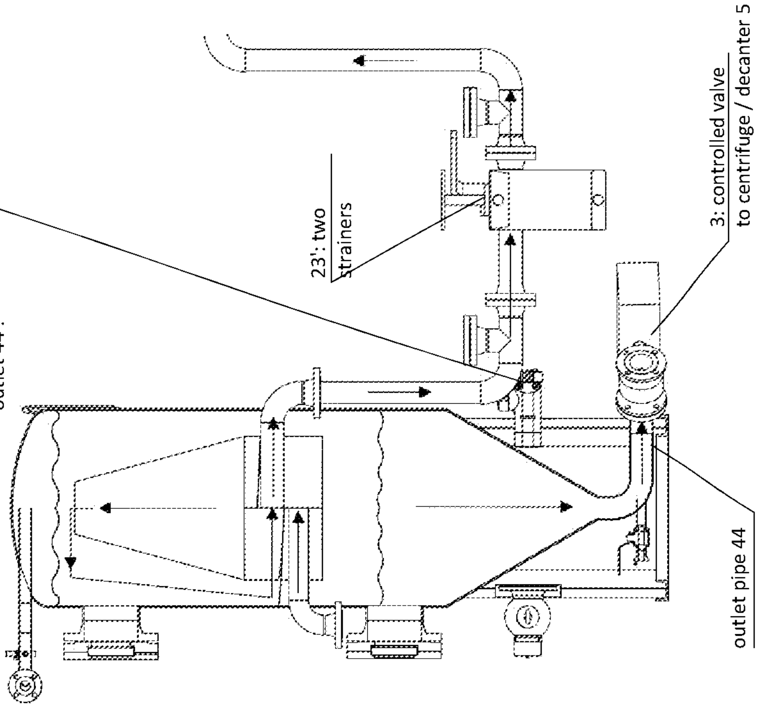


Fig. 4d: Embodiment with (manual) strainer and radioactive sensor control for valve 3,