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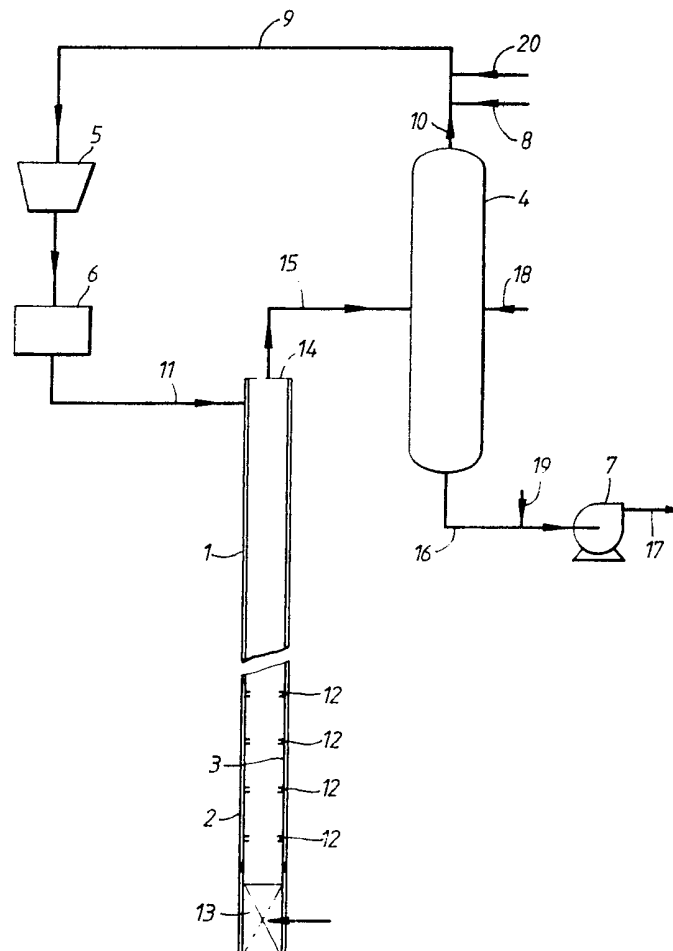
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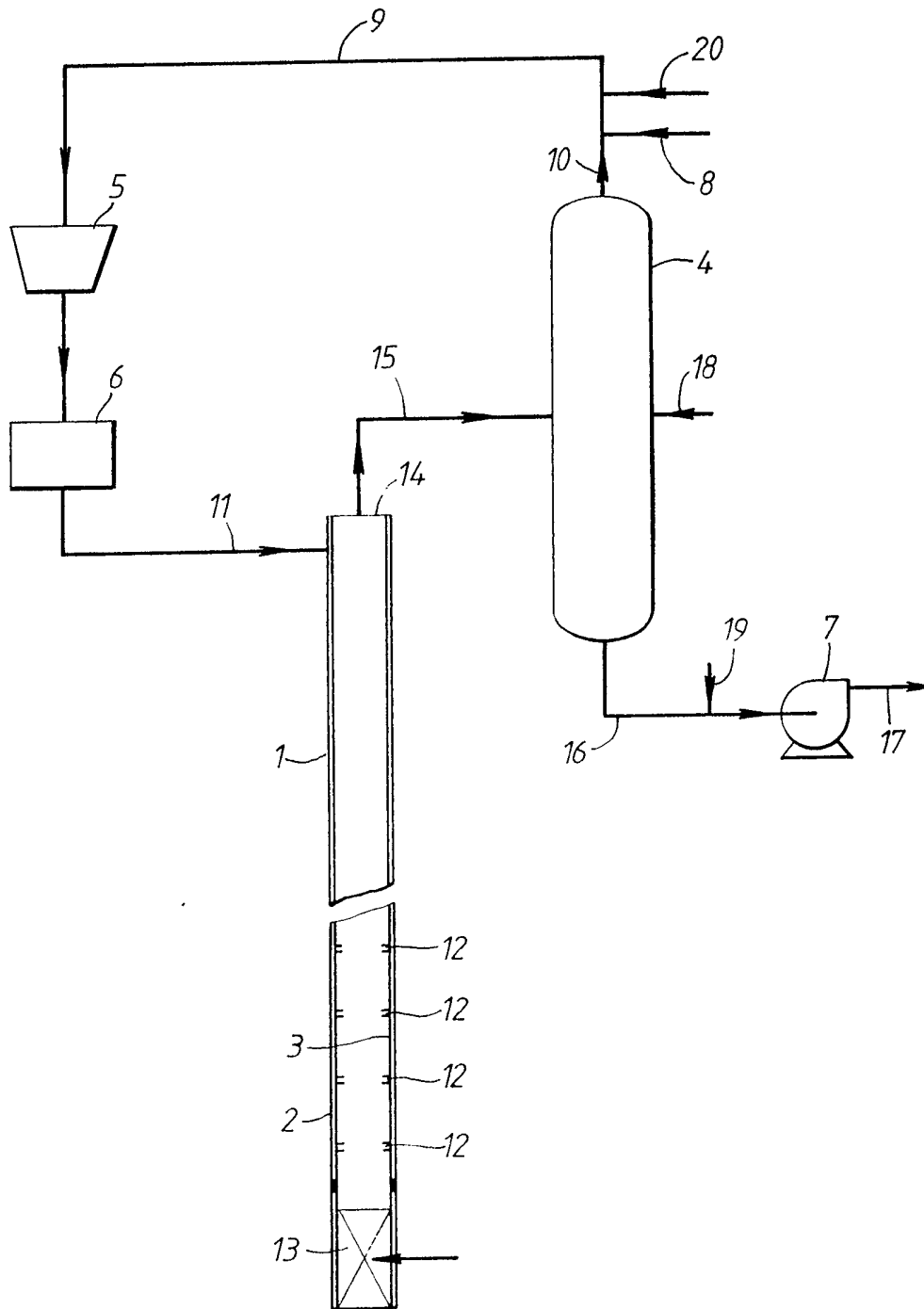
(54) **Water deaeration process**

(57) A process for deaerating water in an upright column (1) immersed in a body of water and equipped at its lower end with an electrical pump (13) which, essentially, provides the water lift in the column, comprises injecting into the upright column, (1) at at least one injection point (12) situated above the electrical pump, fine bubbles of an inert gas, for example purified nitrogen.



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SPECIFICATION

Water deaeration process

5 The present invention relates to the deaeration of water abstracted from a stretch of water, for example the sea, or from an underground water-bearing stratum for a use in which the presence of oxygen would lead to serious disadvantages, particularly corrosion. A particularly important use is the supply of water for assisted recovery of hydrocarbons.

10 It is known that water deaeration can be carried out in vacuum towers or in towers employing entrainment by a gas stream.

15 The principle of the vacuum tower consists in reducing the pressure of the gas phase down to the vapour pressure of water (0.035 bar at 25°C) by means of vacuum pumps. The water to be degassed enters at the top of a stage, being distributed over the whole cross-section of the tower by means of a perforated distributor or a system of atomizing nozzles. The contact surface between water and gas

20 along the tower is provided by flow over packings such as rings, saddles, woven media, and the like. Conventional towers generally incorporate one to three stages, each three to four metres high, with vacuum take-offs arranged in the intermediate spaces. From an economic standpoint it is preferable to employ two-stage towers and to carry out a final degassing chemically in a capacity arranged at the bottom of the tower.

35 In towers employing entrainment by a gas stream, entrainment of the dissolved gases present in the liquid phase is produced by subjecting the latter to a counter-current passage of another gas whose content of the gas to be removed (in this case oxygen) is as low as possible: natural or inert gas. These towers are quite similar to the vacuum towers. The water to be degassed enters at the top of the tower and the entrainment gas just above the storage capacity arranged at the bottom of the tower, the ratio of the volumes of entrainment gas and water to be treated being between 1 and 2. As in the case of vacuum towers, the contact surface between the water and gas

45 can be provided by packings, but it can also be produced by a series of plates. In order for the number of plates to be economically acceptable, a final degassing is generally carried out by a chemical method, as in the case of vacuum towers.

50 It has recently been proposed to carry out the pumping and the degassing of the water simultaneously by means of a process known as "gas-lift", consisting in injecting an inert gas under pressure at the bottom of an upright column immersed in the stretch of water and open at its bottom end, so that this inert gas drags the water present in this column upwards and at the same time releases most

65 of the oxygen dissolved in the water which it

entrains.

70 This process, theoretically attractive, requires very bulky plants which are not readily compatible with the very restricted space available on a platform at sea.

In point of fact, the two functions which the injected gas is to fulfil, that of lifting the water by pumping and of deaerating it, are contradictory; when the intention is to deaerate the water, the volume of the injected gas does not need to be great, but because of the fact that the energetic efficiency of this gas for lifting the water is low, large quantities of injection gas need to be conveyed; the gas compression and separation units are then very bulky.

80 According to the present invention there is provided a process for deaerating water in an upright column immersed in a body of water, or an underground water-bearing stratum, said column being open at its lower end and provided in the region of said open end with an electrical pump which lifts the water in the column, comprising injecting into said upright column, at at least one injection point situated

85 above said electrical pump, an inert gas under a pressure which is at most equal to the hydrostatic pressure of the column full of water at the level of the injection point.

90 Preferably the electric pump supplies at least 80% of the energy absorbed by the water lift in the upright column.

95 Preferably, the injection takes place in the form of fine bubbles of gas with a diameter of the order of one millimetre.

100 The chief advantage of an embodiment of a process according to the present invention consists in the possibility of considerably reducing the bulk of the surface plants. On the one hand, the electric pump is submerged and consumes relatively very little electrical energy because of its excellent pumping efficiency (at least five to six times greater than that which would be provided by an injection gas operating as "gas lift" and required to satisfy the conditions for water deaeration); the auxiliary surface equipment required by the presence of the electrical pump consequently does not need to be bulky. On the other hand, the inert gas flow which is strictly

105 necessary for deaerating the water can be optimized depending on the depth of the injection point or points and the size of the injected gas bubbles. This flow is disparately lower (at least twenty times lower) than the gas flow which would be necessary to provide the water lift completely. Even when this flow is adjusted so that the injection gas contributes to the water lift to an extent which is not absolutely negligible but moderate, for example at most approximately 20%, the inert gas compressor and the electrical motor which drives it are very low-powered machines, requiring a relatively minor electrical installation. Since the inert gas flow is low, separation of the gas from water at the surface

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requires a separator which is less bulky and which, above all, is capable of being arranged vertically so as to occupy a minimum ground area: at least 5 to 6 times smaller than the

5 area provided for a conventional horizontal separator employed in the case where the water is lifted wholly by "gas-lift".

An embodiment according to the invention will now be described, by way of example
10 only, with reference to the accompanying drawing.

In the drawing the single figure shows diagrammatically an embodiment of a plant for deaerating water according to the present
15 invention. As shown in the drawing, an upright column 1 incorporating an outer casing 2 and an inner tube 3 is immersed in a stretch of water, not shown, which can be the sea, a lake or an underground water-bearing
20 stratum in a tract of land.

At the surface of the stretch of water or tract of land there is provided a gas/liquid separator 4 which is preferably vertical, a compressor 5 and a catalytic reaction cham-
25 ber 6, together with a transfer pump 7 for the water produced. When a marine plant is involved, this equipment is on a platform, the separator 4 being situated wholly above sea level.

An inert gas, consisting, for example, of purified nitrogen, is introduced via a line 8 into a pipeline 9 connecting the gas outlet 10 of the separator 4 to the inlet of the compressor 5. Since the gas circuit is a closed circuit
35 during operation, the line 8 serves only for additions compensating for losses. The inert gas is compressed in the compressor 5 and then passes into the chamber 6 before being injected via a pipeline 11 at the top of the
40 well into the annular space between the tube 3 and the casing 2 to enter the interior of the tube 3 through diffusers 12.

An electrical pump 13 arranged at the bottom of the upright column 1 below the diffusers 12 pumps water up the tube 3.
45 Advantageously the pump provides at least 80% of the energy required to lift the water to the top of the column.

A mixture consisting, on the one hand, of inert gas and of gas extracted from water by the inert gas and, on the other hand, of water, is collected in a pipeline 15 at the top part 14 of the tube 3. The separator 4 makes it possible to separate this mixture into the
50 gaseous phase obtained at the upper outlet 10 and the liquid phase obtained at the lower outlet 16. The water collected at 16 and compressed by the pump or pumps 7 can be conveyed via the pipeline 17 to filters and to
60 a user unit, for example to injection pumps for an assisted recovery of hydrocarbons.

Provision is made in the separator 4 for an inlet 18 for antifoam agents and downstream of the outlet 16 for an inlet 19 for scaling
65 inhibitors and/or other additives. A line 20

makes it possible to introduce into the pipeline 9 hydrogen intended to react in chamber 6 with the oxygen which has been extracted from the water by the inert gas in the tube 3.

70 In the tube 3 the water is in contact with an inert gas which is poorly soluble in water; this gas is at a pressure P which is at most equal to the hydrostatic pressure of the water and the volume of which is sufficient for the
75 partial pressure of released oxygen P' to remain close to zero. The oxygen dissolved in the water tends to be released so long as its partial pressure in the gas phase remains below a certain value P'_s, the equilibrium
80 being defined by Henry's Law:

$$C = H \cdot P'_s$$

where: C is the concentration of the oxygen dissolved in the water, in kg/m³; H is Henry's constant for oxygen and expressed in kg/m³ Pa; and P'_s is the partial pressure of oxygen in the gas phase in equilibrium with the liquid phase, expressed in Pa. When P' is lower
85 than P'_s oxygen is released from the liquid phase. If P' were higher than P'_s, oxygen would be dissolving. In the present case, since the partial pressure of oxygen in the gas phase is always kept close to zero, oxygen is
90 released all along the tube.

Efforts must be made to make this release as rapid as possible. It is known that the rate of oxygen transfer at the water/gas interface obeys Fick's first law:

$$100 \quad \frac{dC}{dt} = K_L \cdot a^* \cdot H \cdot (P'_s - P')$$

105 where: K_L is an exchange coefficient expressed in m/s, and a* is the specific surface of water/gas exchange, expressed in m⁻¹, the remaining symbols having been defined earlier.

110 Since the coefficient K_L represents a resistance to transfer which is proportionally lower when the liquid is agitated, it can be seen that it is advantageous to create a large specific surface of exchange and high agitation.

115 The size of the gas bubbles increases as they rise in the tube 3, owing to an increase in the mass due to the transfer of dissolved oxygen and owing to a depression due to the rise in the tube. The rate of ascent V of the
120 bubbles increases with their radius R in accordance with Stokes's Law:

$$125 \quad V = 2 \cdot \frac{\Delta \rho \cdot g \cdot r^2}{9\mu}$$

where: Δρ is the difference in density between water and the gas; g the acceleration of gravity; and μ the viscosity of water.

130 These millions of fine gas bubbles the radii

of which increase and which travel faster and faster meet each other, which gives rise, despite the negative role of surfactants played by the organic substances present in the water, to some coalescence which contributes to the increase in the size of the bubbles as they ascend.

The separator 4, which receives the water/gas mixture leaving the column 1, makes it possible to separate the gas bubbles. Since the gas volume is relatively small, it is possible to employ a vertical separator having a water retention time of the order of 2 minutes and to supplement the degassing chemically by the injection of sulphites. This separator forms a sufficient capacity upstream of the pumps 7.

The inert gas is recovered, to be recycled, at the top of the separator 4 after passing through a dehumidifier, not shown, to avoid carry-over of water into the gas recycling circuit.

The small quantity of inert gas which is introduced continuously or periodically at 8 is adjusted to compensate for the quantity of inert gas which has dissolved in the water, by monitoring the gas flow at the outlet of the separator 4. Storage of inert gas does not present a problem, given the low consumption of this gas.

The stoichiometric quantity of hydrogen introduced at 20 to react in the chamber 6 with the oxygen extracted from the water is produced either by an electrolyser employing the water available locally or by a generator employing methanol.

The compressor 5 recompresses the gas to a pressure close to the injection pressure. In the chamber 6, the gas passes through a catalyst bed which makes the oxygen and hydrogen react to form water vapour. The temperature at the outlet of the compressor 5 must be at least 130°C if good efficiency of the catalyst bed is to be obtained. At the outlet of the chamber 6, the regenerated inert gas contains less than 1 ppm of oxygen.

Another process for extracting oxygen from the gas to be recycled could be employed if appropriate.

There is thus provided a process in which the functions of lifting the water and deaerating the water in the column are separated so that each can be implemented under optimum conditions.

CLAIMS

1. A process for deaerating water in an upright column immersed in a body of water, or an underground water-bearing stratum, said column being open at its lower end and provided in the region of said open end with an electrical pump which lifts the water in the column, comprising injecting into said upright column, at at least one injection point situated above said electrical pump, an inert gas under

a pressure which is at most equal to the hydrostatic pressure of the column full of water at the level of the injection point.

2. A process according to claim 1, wherein said electrical pump supplies at least 80% of the energy absorbed by the water lift in the upright column.

3. A process according to either claim 1 or claim 2, wherein said inert gas is injected into said upright column in the form of fine gas bubbles with a diameter of the order of one millimetre.

4. A process according to any one of the preceding claims, including separating, in a vertical separator, the gaseous and liquid phases obtained as a mixture at the top of said upright column.

5. A process for deaerating water according to claim 4, including recycling said gaseous phase separated in said separator, after compression, extraction of oxygen and addition of a quantity of inert gas compensating for any losses of said inert gas due to dissolving in water.

6. A process for deaerating water substantially as herein described with reference to the accompanying drawing.

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