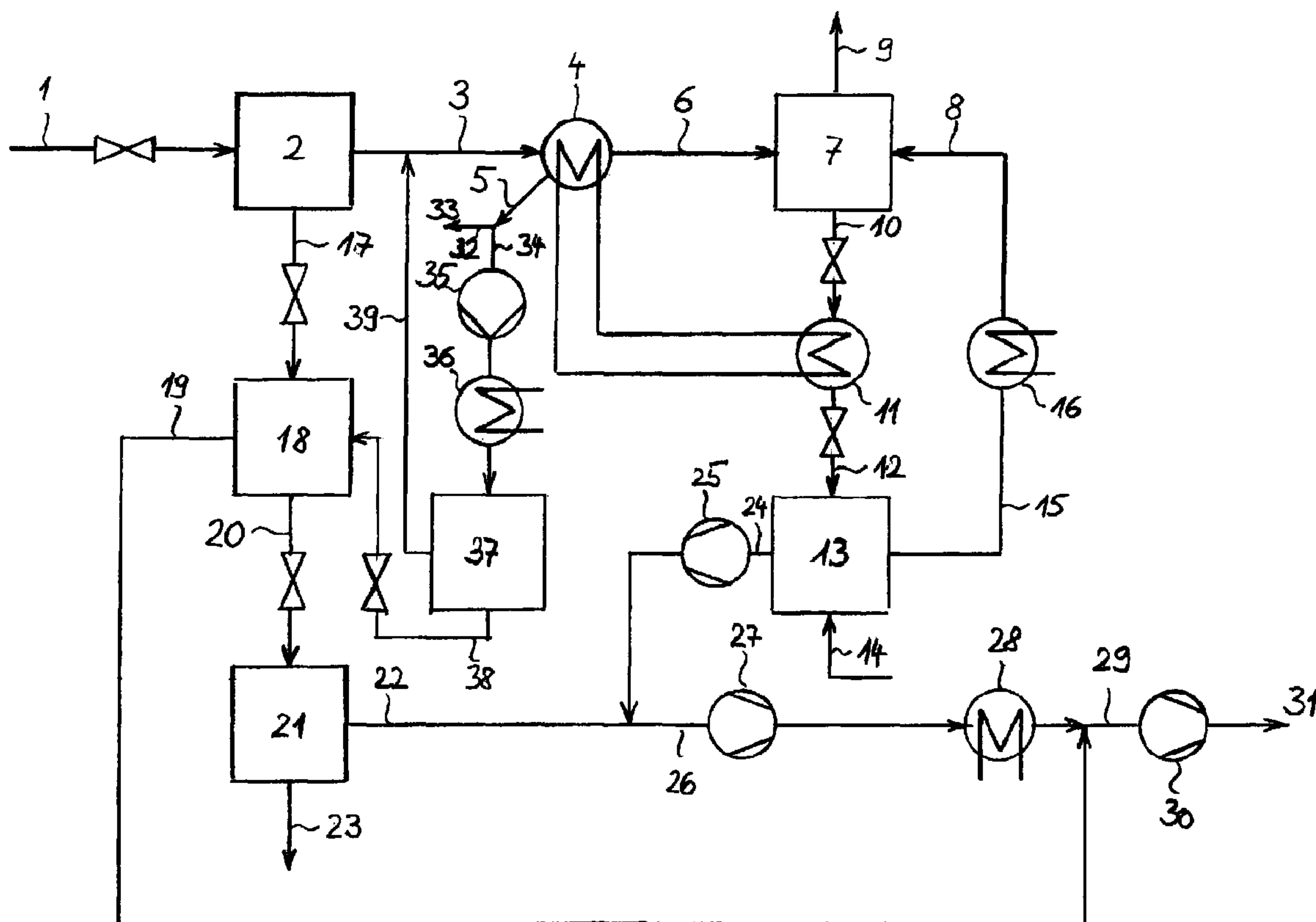


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(54) Title: PROCESS TO REDUCE THE HYDROGEN SULPHIDE CONTENT OF NATURAL GAS OBTAINED DURING THE EXTRACTION OF CRUDE OIL/NATURAL GAS MIXTURES



Process to reduce the hydrogen sulphide content of natural gas obtained from the extraction of sour gas-containing crude oil/natural gas mixtures, by first reducing the high pressure the raw crude oil/natural gas mixture is under to between 70 and 130 bar – preferably 90 bar -, separating the outgassing raw gas from the crude oil and cooling said gas, at the same time drawing off

(57) **Abrégé(suite)/Abstract(continued):**

the liquid medium as it condenses during said cooling, following said cooling and without any further action to reduce the pressure, subjecting the outgassed raw gas to gas scrubbing, which absorbs a large part of the H_2S contained in the raw gas by means of a physically active solvent, thus cleaning the raw gas, directing the laden solvent to at least one pressure reduction step, feeding the heat given off during the cooling of the raw gas to the laden solvent, letting the dissolved H_2S outgas from the solvent, cooling the solvent thus regenerated and returning it to the gas scrubber, further reducing the pressure of the crude oil from 70-130 bar to 20-40 bar – preferably 30 bar – in a subsequent step and separating the additional H_2S -rich raw gas from the crude oil as it outgases therefrom, again reducing the pressure of the crude oil from 20-40 bar to 2-15 bar – preferably 10 bar – and separating the additional raw gas from the crude oil as it outgases therefrom, bringing the H_2S -containing gas outgassed from the solvent to the same pressure as the H_2S -rich raw gas outgassed from the crude oil and combining all outgassed H_2S -containing gas streams, bringing this combined H_2S -containing gas stream to a pressure above that of the crude oil reservoir and feeding it into a well in said crude oil reservoir.

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Abstract

Process to reduce the hydrogen sulphide content of natural gas obtained from the extraction of sour gas-containing crude oil/natural gas mixtures, by first reducing the high pressure the raw crude oil/natural gas mixture is under to between 70 and 130 bar – preferably 90 bar -, separating the outgassing raw gas from the crude oil and cooling said gas, at the same time drawing off the liquid medium as it condenses during said cooling, following said cooling and without any further action to reduce the pressure, subjecting the outgassed raw gas to gas scrubbing, which absorbs a large part of the H₂S contained in the raw gas by means of a physically active solvent, thus cleaning the raw gas, directing the laden solvent to at least one pressure reduction step, feeding the heat given off during the cooling of the raw gas to the laden solvent, letting the dissolved H₂S outgas from the solvent, cooling the solvent thus regenerated and returning it to the gas scrubber, further reducing the pressure of the crude oil from 70-130 bar to 20-40 bar – preferably 30 bar – in a subsequent step and separating the additional H₂S-rich raw gas from the crude oil as it outgases therefrom, again reducing the pressure of the crude oil from 20-40 bar to 2-15 bar – preferably 10 bar – and separating the additional raw gas from the crude oil as it outgases therefrom, bringing the H₂S-containing gas outgassed from the solvent to the same pressure as the H₂S-rich raw gas outgassed from the crude oil and combining all outgassed H₂S-containing gas streams, bringing this combined H₂S-containing gas stream to a pressure above that of the crude oil reservoir and feeding it into a well in said crude oil reservoir.

Process to reduce the hydrogen sulphide content of natural gas obtained during the extraction of crude oil/natural gas mixtures

[0001] The invention relates to a process for reducing hydrogen sulphide in natural gas. When crude oil is extracted, it occasionally comprises large amounts of natural gas. This natural gas may contain a significant amount of hydrogen sulphide (H_2S), the H_2S content often exceeding 5% and in some cases even 20% - in both cases in relation to volume under standard conditions. This raw gas is dissolved in the crude oil under the high pressure prevailing in oilfields. During extraction, subsequent transportation and refining of the crude oil, this raw gas outgases from the crude oil.

[0002] The high H_2S content of the raw gas poses a problem, particularly with regard to safety: H_2S is a highly poisonous respiratory toxin for humans, animals and plants. In the event of a leak or accident the usually high volumetric flow rates from a well could quickly lead to such a substantial amount of highly toxic H_2S being released into the surroundings as to pose a considerable threat of harm to workers and the environment and oil extraction would have to be stopped immediately.

[0003] This is an even greater problem when oil extraction is located on an oil platform and the quick evacuation of all personnel in an emergency cannot always be guaranteed. In view of the rough conditions at sea, any process offering a solution should therefore be extremely robust and also space-saving.

[0004] Another problem is what to do with the H_2S . Admittedly, it could be processed into sulphur dioxide, sulphur and sulphuric acid using a common process. This would however entail immense costs if done on site and, if this were not possible, transport problems would arise.

[0005] Hence, the purpose of the invention is to provide a safe and particularly compact process which allows a substantial reduction in the H_2S content of natural gas at the place of extraction, while at the same time offering a safe and robust design and furthermore ensuring that the H_2S is dealt with safely.

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[0006] The invention achieves this purpose as stated by

- first reducing the high pressure the raw crude oil/natural gas mixture is under to between 70 and 130 bar - preferably 90 bar
- separating the outgassing raw gas from the crude oil and cooling said gas
- 5 • at the same time drawing off the liquid medium as it condenses during said cooling
- following said cooling and without any further action to reduce the pressure, subjecting the outgassed raw gas to gas scrubbing, which absorbs a large part of the H₂S contained in the raw gas by means of a physically active solvent, thus cleaning the raw gas
- 10 • directing the laden solvent to at least one pressure reduction step
- feeding the heat given off during the cooling of the raw gas to the laden solvent
- letting the dissolved H₂S outgas from the solvent
- cooling the solvent thus regenerated and returning it to the gas scrubber
- further reducing the pressure of the crude oil from 70-130 bar to 20-40 bar -
- 15 preferably 30 bar - in a subsequent step and separating the additional H₂S-rich raw gas from the crude oil as it outgases therefrom
- again reducing the pressure of the crude oil from 20-40 bar to 2-15 bar - preferably 10 bar - and separating the additional raw gas from the crude oil as it outgases therefrom
- 20 • bringing the H₂S-containing gas outgassed from the solvent to the same pressure as the H₂S-rich raw gas outgassed from the crude oil and combining all outgassed H₂S-containing gas streams

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- bringing this combined H₂S-containing gas stream to a pressure above that of the crude oil reservoir and feeding it into a well in said crude oil reservoir.

[0006a] In one aspect, the invention relates to a process for reducing the hydrogen sulphide (H₂S)-content of natural gas (9) obtained during the outgassing of H₂S-containing crude oil/natural gas mixtures (1) which have been extracted from a crude oil reservoir (31), by:

- first reducing (2) the high pressure of the H₂S-containing raw crude oil/natural gas mixture (1) to a pressure between 70 and 130 bar;
- separating an outgassing raw gas (3) from a crude oil (17) and cooling (4) said outgassing raw gas (3);
- at the same time drawing off a liquid medium which condenses (5) during said cooling (4) of the outgassing raw gas (3);
- following said cooling (4) and without any further action to reduce the pressure, subjecting the outgassed raw gas (6) to gas scrubbing (7), which absorbs a large part of the H₂S contained in the raw gas by means of a physically active solvent (8), thus cleaning the outgassed raw gas (6);
- directing the laden solvent (10) from the gas scrubbing (7) to at least one pressure reduction step;
- feeding the heat given off during the cooling (4) of the raw gas (3) to the laden solvent (10);
- permitting the dissolved H₂S to outgas (13) from the laden and heated solvent (12), thus obtaining a regenerated solvent (15) and an H₂S-containing off-gas (24);
- cooling (16) the regenerated solvent (15) and returning the regenerated solvent (15) to the gas scrubber (7);

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- further reducing the pressure of the crude oil (17) from 70-130 bar to 20-40 bar in a subsequent step (18) and separating an additional H₂S-rich raw gas (19) which outgases from the crude oil (17);

- again reducing the pressure (21) of the crude oil (20), which has separated from the additional H₂S-rich raw gas (19), from 20-40 bar to 2-15 bar and separating a low-pressure H₂S-containing gas (22) which outgases from the crude oil (20);

- bringing the H₂S-containing off-gas (24) that has outgassed from the laden and heated solvent (12) to the same pressure as the low-pressure H₂S-containing gas (22) outgassed from the crude oil (20) and combining all H₂S-containing gas streams (19, 22, 24) which have outgassed from the crude oil (17, 20) and the laden and heated solvent (12), thus obtaining a combined H₂S-containing gas stream (29); and

- bringing this combined H₂S-containing gas stream (29) to a pressure above the pressure of the crude oil reservoir (31) and feeding the combined H₂S-containing gas stream (29) into a well in said reservoir (31).

15 **[0007]** In this way a large part of the H₂S extracted is used to maintain the discharge pressure of the crude oil reservoir, which improves the possible overall oil and gas yields. However, it should be borne in mind that in the long term returning this gas leads to an accumulation of H₂S in the raw gas extracted from said crude oil reservoir.

20 **[0008]** It is therefore all the more important that the described process also ensures the safe, economical processing of very high concentrations of H₂S by simply allowing a higher percentage of the liquid medium which condenses as the raw gas is cooled, thereby absorbing a large part of the H₂S contained in the raw gas, to be drawn off in line with the increased H₂S content in the raw gas. This is one
25 advantage of said invention. There are a range of alternatives for utilising the liquid medium, and these

may be used alternately or cumulatively in the case of a continuous rise in the H₂S content.

5 **[0009]** One embodiment of the process according to the invention therefore envisages pumping the liquid medium drawn off after cooling the raw gas into a well in the crude oil reservoir.

10 **[0010]** In a second embodiment of the process according to the invention, the pressure of the condensed liquid medium is reduced to the same pressure as the crude oil, i.e. between 20-40 bar and preferably 30 bar, at the same time combining the gas medium formed with the gas medium outgassing from the crude oil and combining the remaining liquid medium with the crude oil. In practice, this can be done by expanding both the crude oil and the drawn off liquid medium into the same evaporation drum.

15 **[0011]** In a third embodiment of the process according to the invention, the liquid medium which condenses during the cooling of the raw gas outgassed from the crude oil is subjected to throttling, causing it to evaporate completely and cool in accordance with the Joule-Thomson effect – the resulting cold being used to cool the regenerated solvent and the H₂S-containing gas stream being combined with the other
20 H₂S-containing gas streams after compression.

[0012] The liquid medium which condenses out can first be treated to enrich its H₂S content before being subjected to the above. A further embodiment of the process according to the invention therefore envisages using a pump to slightly increase the
25 pressure of the liquid medium drawn off after cooling the raw gas, feeding this liquid medium to a preheater to be heated to approximately 70°C - which creates a two-medium system with the release of mainly volatile hydrocarbons as the gas medium – then returning this gas medium to the raw gas upstream of the raw gas cooler, achieving an accordingly enriched H₂S content of the remaining liquid medium.

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[0013] Here, the slight pressure increase need only be enough to compensate for the pressure losses which occur so that the gas medium formed can be returned upstream of the raw gas cooler. It may also be appropriate to cool the remaining liquid medium – the heat, at least partly, being released in an internal heat exchange process
35 to the medium drawn off after the cooling of the raw gas. This is particularly true if the liquid medium is to be subsequently used to generate cold.

[0014] To improve solvent regeneration an additional regeneration step based on pressure reductions may be included, as envisaged in European patent specification 0 920 901 B1. In a further embodiment of the process according to the invention the final solvent pressure reduction step is designed and operated as a low-pressure stripping column and purified natural gas is used as the stripping gas.

[0015] The simultaneous absorption of higher hydrocarbons cannot always be avoided when a physical solvent is used. These useful components, which are also separated out are, according to the invention, returned to the crude oil reservoir for the moment along with the H_2S . As soon as the accumulation of H_2S in the crude oil reservoir leads to an increased H_2S concentration in the H_2S scrubbing stage, the hydrocarbons are however adsorptively displaced by the more easily absorbed H_2S and an ever greater percentage of higher hydrocarbons gets into the pre-purified natural gas. Consequently, these hydrocarbons are not lost on a long-term basis; it is just that they tend to be exploited at a later date.

[0016] In a further embodiment of the process according to the invention a mixture of N-formylmorpholine (NFM) and N-acetylmorpholine (NAM) is used as solvent, as described in European patent specification 0 920 901 B1. The sour gas scrubbing process can be used in a similar manner as described therein but a high standard of product gas purity and thus regeneration of the solvent cannot be expected. A suitable location for use is for example an oil platform.

[0017] Compared with other methods, a scrubbing process using a physical solvent has the advantage that it requires only a very small circulation loop for the scrubbing agent and can be built very compactly. Sensitive parts, such as thin membranes, etcetera, are not used. The use of pressure reduction devices to regenerate the solvent obviates the need for external regeneration energy, such as steam, thus enabling an even more compact design, which is an advantage of the invention.

[0018] The invention is explained in greater detail below by means of an example design. At the same time, Fig. 1 shows a block diagram of the process installed on an oil platform – the valves illustrated representing pressure reduction devices which, however, could alternatively be designed as reverse rotation pumps and compressors (expanders).

[0019] The pressure of the warm crude oil/raw gas mixture (1) extracted from the crude oil reservoir is reduced from approximately 800 to 95 bar in the high-pressure separator (2), where two media are formed during cooling - a liquid crude oil medium and a gaseous raw gas medium. These two media are separated in the high-pressure separator (2). The gas medium is cooled as raw gas (3) to approximately 10°C in the raw gas cooler (4), which may also be of a multi-stage design. During cooling a liquid medium (5) condenses out. The cooled raw gas (6) is then scrubbed in the scrubber (7) using the scrubbing agent (8), with most of the H₂S present in the raw gas being absorbed in the scrubbing agent. The pre-treated natural gas (9) leaves the scrubber (7) and is conveyed via a pipeline to an external natural gas treatment station, where on-spec. natural gas is produced.

[0020] The pressure of the saturated H₂S-laden scrubbing agent (10) is reduced in several steps and at the same time heated in the heater (11) connected to the cooler (4), thus reducing the solubility of the H₂S, allowing a particularly large amount of H₂S to be stripped at ambient pressure in an advantageous manner from the heated scrubbing agent (12) in the low-pressure stripping column (13) by means of at least partially purified natural gas (14), which can, for example, be drawn off from the pre-treated natural gas (9). The stripped scrubbing agent (15) is cooled to use temperature in the scrubbing agent cooler (16) and returned to the scrubber (7).

[0021] The pressure of the high-pressure crude oil (17) recovered from the high-pressure separator (2) is reduced to 30 bar in the medium-pressure separator (18), where additional dissolved gas components outgas from the crude oil and are drawn off as medium-pressure raw gas (19).

[0022] The pressure of the medium-pressure crude oil (20) removed from the medium-pressure separator (18) is further reduced to 9 bar in the low-pressure separator (21), where additional dissolved gas components again outgas from the crude oil and are drawn off as low-pressure raw gas (22). The low-pressure crude oil (23) from the low-pressure separator (21) is conveyed via a pipeline or by ship to an external refinery, where it is further refined.

[0023] The off-gas (24) leaving the low-pressure stripping column (13) is compressed to the pressure of the low-pressure raw gas in the off-gas compressor (25) and combined with the low-pressure raw gas (22). If – not shown here – any other H₂S-containing gas streams to which the saturated scrubbing agent or expanded,

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evaporated condensate (5) is subjected occur, for instance downstream of the pressure reduction devices, these streams can also be integrated at this point, or upstream of the off-gas compressor (25) if their pressure is otherwise not sufficient.

5 [0024] The low-pressure sour gas (26) is brought to the pressure level of the medium-pressure separator (18) in the low-pressure compressor (27) and, after being cooled in the low-pressure cooler (28), combined with the medium-pressure raw gas (19). The combined medium-pressure sour gas (29) is then compressed to reservoir pressure in the high-pressure compressor (30) and fed into the crude oil
10 reservoir (31).

[0025] After being cooled in the raw gas cooler (4) to approximately 10°C, the condensed liquid medium (5) is separated into two part streams. One of the part streams (32) is pumped to the crude oil reservoir (33) – the pumps are, however, not
15 shown in the diagram. The pressure of the other part stream (34) is slightly raised by means of the delivery pump (35) and heated to 70°C in the heater (36).

[0026] The outgassing gas medium and the remaining liquid medium are separated from each other in the media separation unit (37). The pressure of the liquid
20 medium (38) is reduced to the pressure in the medium-pressure separator (18) and fed into this separator (18). The gas medium (39) is mixed with the raw gas (3).

[0027] Consequently, of the original H₂S content of the crude oil/raw gas mixture (1), approximately 83% remains in the crude oil reservoir (31), approximately 10% in
25 the pre-treated raw gas (8) and approximately 7% in the crude oil, resulting in a significant reduction in the risks of environmental damage and hazards.

[0028] List of reference numbers

- 1 Crude oil/raw gas mixture
- 2 High-pressure separator
- 3 Raw gas
- 4 Raw gas cooler
- 5 Condensate
- 6 Cooled raw gas
- 7 Scrubber
- 8 Scrubbing agent
- 9 Pre-treated natural gas
- 10 Saturated scrubbing agent
- 11 Heater
- 12 Heated scrubbing agent
- 13 Low-pressure stripping column
- 14 Stripping gas
- 15 Stripped scrubbing agent
- 16 Scrubbing agent cooler
- 17 High-pressure crude oil
- 18 Medium-pressure separator
- 19 Medium-pressure raw gas
- 20 Medium-pressure crude oil
- 21 Low-pressure separator
- 22 Low-pressure raw gas
- 23 Low-pressure crude oil
- 24 H₂S off-gas
- 25 Off-gas compressor
- 26 Low-pressure sour gas
- 27 Low-pressure compressor
- 28 Low-pressure cooler
- 29 Medium-pressure gas
- 30 High-pressure compressor
- 31 Crude oil reservoir
- 32 Part stream
- 33 Crude oil reservoir
- 34 Part stream
- 35 Delivery pump

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- 36 Heater
- 37 Media separation unit
- 38 Liquid medium
- 39 Gas medium

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CLAIMS:

1. A process for reducing the hydrogen sulphide (H₂S)-content of natural gas (9) obtained during the outgassing of H₂S-containing crude oil/natural gas mixtures (1) which have been extracted from a crude oil reservoir (31), by:
- 5 • first reducing (2) the high pressure of the H₂S-containing raw crude oil/natural gas mixture (1) to a pressure between 70 and 130 bar;
- separating an outgassing raw gas (3) from a crude oil (17) and cooling (4) said outgassing raw gas (3);
- at the same time drawing off a liquid medium which condenses (5)
- 10 during said cooling (4) of the outgassing raw gas (3);
- following said cooling (4) and without any further action to reduce the pressure, subjecting the outgassed raw gas (6) to gas scrubbing (7), which absorbs a large part of the H₂S contained in the raw gas by means of a physically active solvent (8), thus cleaning the outgassed raw gas (6);
- 15 • directing the laden solvent (10) from the gas scrubbing (7) to at least one pressure reduction step;
- feeding the heat given off during the cooling (4) of the raw gas (3) to the laden solvent (10);
- permitting the dissolved H₂S to outgas (13) from the laden and heated
- 20 solvent (12), thus obtaining a regenerated solvent (15) and an H₂S-containing off-gas (24);
- cooling (16) the regenerated solvent (15) and returning the regenerated solvent (15) to the gas scrubber (7);

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- further reducing the pressure of the crude oil (17) from 70-130 bar to 20-40 bar in a subsequent step (18) and separating an additional H₂S-rich raw gas (19) which outgases from the crude oil (17);

- again reducing the pressure (21) of the crude oil (20), which has
5 separated from the additional H₂S-rich raw gas (19), from 20-40 bar to 2-15 bar and separating a low-pressure H₂S-containing gas (22) which outgases from the crude oil (20);

- bringing the H₂S-containing off-gas (24) that has outgassed from the laden and heated solvent (12) to the same pressure as the low-pressure
10 H₂S-containing gas (22) outgassed from the crude oil (20) and combining all H₂S-containing gas streams (19, 22, 24) which have outgassed from the crude oil (17, 20) and the laden and heated solvent (12), thus obtaining a combined H₂S-containing gas stream (29); and

- bringing this combined H₂S-containing gas stream (29) to a pressure
15 above the pressure of the crude oil reservoir (31) and feeding the combined H₂S-containing gas stream (29) into a well in said reservoir (31).

2. The process according to claim 1, wherein in the first pressure reduction (2) the high pressure of the H₂S-containing raw crude oil/natural gas mixture (1) is reduced (2) to a pressure of 90 bar, and in a subsequent step the
20 pressure of the crude oil (17) is further reduced (18) from a pressure of 90 bar to 30 bar and in a further pressure reducing step (21) the pressure of the crude oil (20) is reduced from a pressure of 30 bar to 10 bar.

3. The process according to claim 1 or 2, wherein the liquid medium (5) drawn off after the raw gas (3) has been cooled by a raw gas cooler (4) is pumped
25 into a well in the crude oil reservoir (33).

4. The process according to claim 1 or 2, wherein the pressure of the condensed liquid medium (38), which is obtained from the liquid medium (5) drawn

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off after the raw gas (3) has been cooled by a raw gas cooler (4), raised in pressure by means of the delivery pump (35), heated to 70°C in the heater (36) and separated off in the media separation unit (37), is reduced to the same level as that of the crude oil (17), namely 20-40 bar and the gas medium thus formed is combined with the gas medium (19) outgassing from the crude oil and the remaining liquid medium is combined with the crude oil (20).

5. The process according to claim 1 or 2, wherein the liquid medium (5) obtained from cooling (4) the raw gas (3) is subjected to throttling, during which it evaporates and cools in accordance with the Joule-Thomson effect - the resulting cold being used to cool the regenerated solvent (15) and the H₂S-containing gas stream (24) being combined with the other H₂S-containing gas streams (19, 22) following compression.

6. The process according to any one of the claims 1 to 5, wherein the liquid medium (34) which is obtained as a part stream (34) from the liquid medium (5) drawn off after the raw gas (3) has been cooled by a raw gas cooler (4) is first subjected to a pressure increase by means of a pump (35) before being fed to a preheater (36), where a two-medium system forms with the release of mainly readily volatile hydrocarbons as a gas medium (39), this gas medium being returned to the raw gas (3) upstream of the raw gas cooler (4), achieving an accordingly enriched H₂S-content of the remaining liquid medium (38).

7. The process according to claim 6, wherein the remaining liquid medium (38) is cooled and the heat, at least partly, being released to the medium (5) drawn off after the cooling of the raw gas (3).

8. The process according to any one of the claims 1 to 7, wherein the pressure reduction step of the laden and heated solvent (12) is designed and operated as a low-pressure stripping column (13) and purified natural gas (9) is used as the stripping gas (14).

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9. The process according to any one of the claims 1 to 8, wherein a mixture of N-formylmorpholine and N-acetylmorpholine is used as the physically active solvent (8).

Fig. 1