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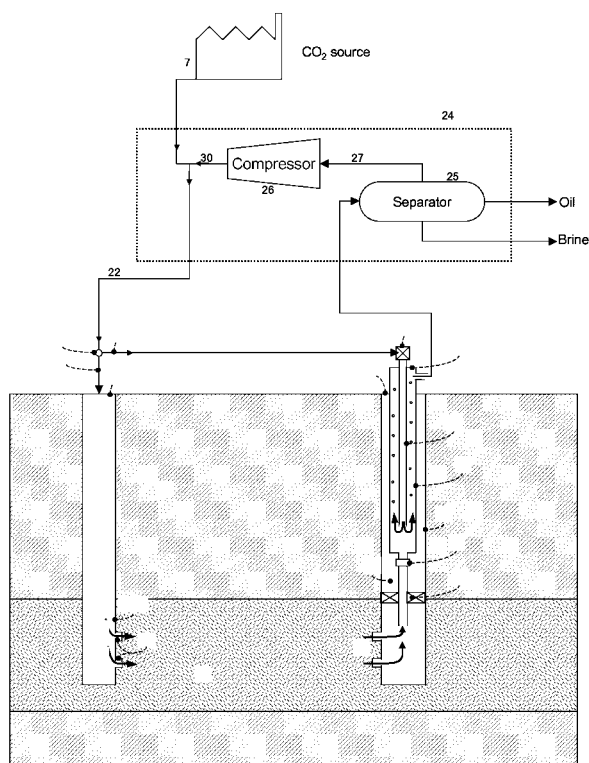
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(54) **Integrated method and system for acid gas-lift and enhanced oil recovery using acid gas background of the invention**

(57) A method of enhancing crude oil recovery from a crude oil containing formation uses an integrated acid gas injection system, which injects a first fraction of an

available volume of acid gas into the formation and a second fraction of the available volume of acid gas as a lift gas into a crude oil production well traversing the formation.



Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method for an integrated system for acid gas-lift and Enhanced Oil Recovery (EOR) by miscible or sub-miscible displacement from a crude oil containing formation by injecting acid gas into the formation.

[0002] US patent 5,337,828 discloses a method of using CO₂ for gas lifting heavy oil, wherein the CO₂ is injected into an heavy crude oil production well through an injection conduit arranged within a crude oil production tubing within the well, thereby avoiding injection of CO₂ into an annulus between the production tubing and well casing and inhibiting formation of a corrosive mixture of CO₂ and water within the annulus.

[0003] It is also known to inject acid gas at high pressure into a crude oil containing formation to enhance oil recovery from the formation by miscible or sub-miscible displacement. Enhanced Oil Recovery (EOR) projects using miscible gas, such as CO₂ and/or H₂S, for injection usually require the production of reservoirs at high watercuts. Flowing producers under these conditions require some form of artificial lift (e.g. electric submersible pumps (ESPs), hydraulic submersible pumps (HSPs), jet pumps or gas lift).

[0004] In CO₂ EOR projects, CO₂ is typically injected in slugs alternating with periods of water injection. Initially the producers usually flow at very high watercuts and require artificial lift. As injected CO₂ progressively breaks through at the producers together with incremental oil production, the lift performance of the wells improve as the column density is reduced. This is mainly due to the expanding CO₂ in the production tubing when it travels up from the bottom of the well to surface. Eventually the producers reach a point of autolift, where no artificial lift is any longer needed. During the time when back produced CO₂ builds up, significant fluctuations in gas rate can occur (depending on the detail of the geology), so the well may experience periods of autolift followed by periods when artificial lift is required to maximise offtake rates and project economics. At the end of the CO₂ WAG (Water Alternating Gas) injection period, a water post-flush is implemented to recover mobile CO₂ for recycling to new patterns and to continue producing incremental oil. During this period the produced gas rate decreases to a point where once again artificial lift may be needed to fully exploit the last stages of pattern production.

[0005] During CO₂ assisted EOR operations a significant fraction of the total injected CO₂ is back produced and needs to be recycled. This means that surface facilities must be able to handle large volumes of gas and recompress these to high enough pressures to re-inject in the reservoir. In the early years of a CO₂ EOR project the recycled volumes of CO₂ are small and there is typically spare compression capacity available.

[0006] It is an object of the present invention to provide

an integrated method for gas handling for artificial lift and miscible/sub-miscible Enhanced Oil Recovery from a crude containing formation, thereby simplifying surface facilities, reducing capital and operational costs and increasing uptime.

[0007] During the lifetime of a project the combined gas stream of the fresh acid gas and the recycled gas will become contaminated with hydrocarbon gas, with the allocation principles between injection gas for EOR and lift gas remaining the same.

SUMMARY OF THE INVENTION

[0008] In accordance with the invention there is provided a method of enhancing crude oil recovery from a crude oil containing formation using an integrated acid gas injection system which injects a first fraction of an available volume of acid gas into the formation and a second fraction of the available volume of acid gas as a lift gas into a crude oil production well traversing the formation.

[0009] As the lift gas is returned to the surface the recycle compression may be used to reinject it in the reservoir or use it for ongoing gas lift.

[0010] The first acid gas fraction may be injected slugwise into the formation, and injection of acid gas slugs may be alternated by injection of water slugs into the formation.

[0011] The acid gas may comprise CO₂ and/or H₂S with together with hydrocarbon gas or other contaminants obtained from a natural or industrial source and the first fraction may be injected into the formation through an injection well traversing the formation at a distance from the production well such that the first fraction mixes with and displaces crude oil within the pores of the formation by a miscible or sub-miscible process and flows towards the production well.

[0012] At least some part of the first acid gas fraction may be produced through the production tubing and then recycled with the fresh acid gas obtained from natural or industrial sources.

[0013] The rate and/or pressure at which the second acid gas fraction is injected into the injection conduit may be adjusted on the basis of one or more of the following parameters:

- target and/or fluctuation of crude oil production of the production well(s);
- fluctuation of gas production of the production well(s);
- density and/or watercut of the well effluents in the production tubing of the production well(s);
- available acid gas (or produced gas and acid gas mixture) volume and/or acid gas (or produced gas and acid gas mixture) compressor capacity;
- bottom hole pressure in the production well.

[0014] When used in this specification and claims the term acid gas shall mean a gas which contains more than 1 mole% of hydrogen sulfide (H₂S) and/or more than 5 mole% carbon dioxide (CO₂), wherein the acid gas may be obtained from an industrial source (e.g. extracted from furnace or turbine flue gas) and/or natural sources, and may comprise a mixture of CO₂, H₂S and natural gas produced from the crude oil containing formation.

[0015] The integrated acid gas-lift and EOR method according to the invention may be applied to reservoirs where continuous acid gas injection is the preferred secondary recovery method.

[0016] These and other features, embodiments and advantages of the method according to the invention are described in the accompanying claims, abstract and the following detailed description of non-limiting embodiments depicted in the accompanying drawing, in which description reference numerals are used which refer to corresponding reference numerals that are depicted in the drawing.

BRIEF DESCRIPTION OF THE DRAWING

[0017]

Figure 1 is a schematic view of an oil containing formation and production well in which the integrated system for acid gas-lift and acid gas enhanced EOR method according to the invention is applied.

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENT

[0018] Figure 1 shows a crude oil containing formation 1, which is located underneath an overburden 2 and is traversed by an acid gas injection well 3 and a crude oil production well 4. The crude oil production well 4 comprises a well casing 5, which is perforated near the bottom of the well to enable influx of crude oil into the well 4 as illustrated by arrows 6.

[0019] A volume of acid gas obtained from a natural or an industrial acid gas source 7 is distributed to the field well pads or well head platforms through a distribution network 22 and split at a manifold 21 into a first fraction 11, which is injected into the formation 1 through perforations 13 in a well casing 14 within the acid gas injection well 3 as illustrated by arrow 15, and a second fraction 12, which is injected as lift gas into a lift gas injection conduit 16 that is arranged within the interior of a production tubing 17, which is suspended within the well casing 5 from the wellhead 18 of the production well 4. If required, a conventional downhole safety valve 28 can be installed below the lift gas injection string 16 and above a production packer 19. The rate of lift gas injection is controlled by a choke 23. The packer 19 is arranged near the bottom of an annular space 20 between the production tubing 17 and well casing 5 to inhibit crude oil and/or acid gas lift gas to flow into the annular space 20.

[0020] Produced fluids comprising crude oil, brine (mixture of formation water and injected water), associated hydrocarbon gas, acid gas back produced from the reservoir and acid gas injected directly into the producer for gas lift are produced back to a Processing Facility(s) 24 through a flowline 28. The Processing Facility(s) comprises facilities 25 to separate crude oil from brine and the produced gas (largely comprising acid gas with a level of hydrocarbon gas contamination). This produced gas 27 (possibly after extraction of some of the hydrocarbon content) is compressed 26, where it is raised to high pressure for injection into the reservoir or for use in gas-lifting producers. The high pressure gas 30 is combined with the fresh acid gas imported from the industrial source 7 and routed once more to the wells 3 for injection into the reservoir for Enhanced Oil Recovery and to the producers 4 for acid gas lift.

[0021] An advantage of the integrated system is that the second fraction 12 is used for acid gas lift without significant additional CAPEX (Capital Expenditure) using the basic system of surface facilities infrastructure (22, 28 and 24) required for acid gas Enhanced Oil Recovery. Over the lifetime of a crude oil production project at most a small increase in the compression capacity can accommodate all the acid gas lift gas requirements within the same operating mode as is required in any case for the EOR project itself. Since the gas has to be compressed to inject into the formation 1, there is always sufficient pressure to operate a gas lift system without the need for conventional (potentially leaking) gas lift valves. By allocating the volume of lift gas using chokes 23, the artificial lift capacity can be progressively adjusted to match the wells potential and can respond to short term changes in gas production rate from the reservoir.

[0022] A principle drawback of conventional annular acid gas gas-lift is the corrosive nature of acid gas in the presence of brine. Conventional annular gas lift risks corrosion in the annulus 20 and leakage through gas lift valves, making this option less practical on account of the material that would be required for the well casing 5. Even if the lift fluid would be dehydrated there will always be a "dead volume" below the deepest injection valve and above the production packer 19 where due to leakage corrosive fluids can accumulate.

[0023] The method according to the invention benefits from synergies between the EOR produced fluids processing facilities and acid gas lift in a fully integrated system using concentric lift strings to contain the acid gas (or any other configuration that protect the integrity of the well, including but not restricted to the use of a separate tubing within the annulus to convey acid gas to a deep injection point in the production tubing or full CRA casing), to reduce CAPEX and operational complexity compared to artificial lift schemes based on ESPs (or any other artificial lift method requiring a separate supporting surface system).

[0024] Principal benefits of the method according to the invention are summarized in the following paragraphs

1-9:

1. Significant saving in CAPEX and OPEX compared to use of Electrical Submersible Pumps (ESPs) which require a completely separate system with its own operational issues: 5

- Additional electrical generation capacity
- Variable speed drive for each ESP 10
- Power lines to each well head
- Modified well design for ESPs
Especially in case the acid gas EOR operations are carried out offshore the required VSD units and additional electrical generation capacity (if power is generated offshore) will demand significant platform space and weight requirements. 15
In contrast acid gas gas-lift requires only limited modification to the surface facilities 20
- Possible capacity adjustment on required EOR recycle compression, if "spare compression" early in life is insufficient 25
- lift gas drawn from the acid gas injection lines to each well pad/ wellhead platform are required in any case for EOR 30
- modified well design with concentric insert string

2. Corrosion risk minimised through use of a concentric completion that consists of an insert lift gas string of Glass Reinforced Epoxy (GRE) dual lined or Corrosion Resistant Alloy (CRA) within a GRE lined or CRA production tubing. No access to annulus through gas lift mandrels. 35

3. Tapered production string below the depth of the insert string to maximise lift performance and possibility to remove (and potentially re-use) insert string once well autolifts, maximizing well potential. 40

4. Possibility of installing a conventional downhole safety valve below the insert string and above the production packer 45

5. Increased flexibility to manage uncertainty:

- Well rates are uncertain and if acid gas is from a fixed capacity source (e.g. dedicated CO₂ capture plant from flue gas, or associated acid gas from contaminated gas production), sufficient wells must be operating to take available acid gas at all times to maximize project returns. In a low productivity realisation more wells are needed. With an acid gas gas-lift system, the lift gas can easily be reallocated to a larger number of wells (each of which requires a lower lift gas 50
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rate). With ESPs the requirement for a VSD for each well means that additional CAPEX is needed, and in an offshore environment there may not be flexibility to add additional drives.

- A key uncertainty is the speed at which back produced gas builds up and the overall recycling requirement. The gas lift system intrinsically manages this. In a downside outcome with earlier gas breakthrough, more recycling of acid gas is needed, but the extra gas handling is partly offset by the reduced requirement for gas lift as wells move to autolift sooner. Conversely in an upside outcome of reduced gas cycling, more gas lift is needed which exploits the consequent ullage in compression capacity.

5. Reduced operational complexity. The acid gas gas-lift rate can be constantly adjusted to match the back produced gas and production target rate, responding rapidly to fluctuations in produced gas. In contrast ESPs have more restricted operating ranges and may require change out to handle the evolving back produced gas rates.

6. Gas lift has high uptime, effectively driven by the availability of the recycle compression. Once acid gas has broken through, production would usually be shut-in when the recycle is down, irrespective of the lift system. In contrast ESP requires a separate system, and each ESP is itself prone to failure, requiring the use of a rig offshore to workover the well, leading to higher downtime and additional cost.

7. At the well level gas lift with a concentric string is a highly reliable and robust system. ESPs require a higher level of operator awareness and are more susceptible to mishandling. For example, careful startup is needed, potentially handling significant transients arising from segregation of fluids within the wellbore after a shutdown.

8. Use of the spare compression capacity early in the Enhanced Oil Recovery project for acid gas gas-lift reduces the levels of turn down required and improves energy efficiency.

9. Intelligent or Smart well systems may be deployed in producers to improve the efficiency of the acid gas Enhanced Recovery(EOR) method according to the invention. The acid gas gas-lift system is more compatible with Intelligent or Smart well systems as there is no planned requirement to pull the production tubing. In contrast the need to replace ESPs means that a Smart completion requires a wet-connect which is repeatedly used, increasing the risk of failure and therefore loss of the additional data gathering and inflow control afforded by an Intelligent or Sart well system.

Claims

eters:

1. A method of enhancing crude oil recovery from a crude oil containing formation using an integrated acid gas injection system which injects a first fraction of an available volume of acid gas into the formation and a second fraction of the available volume of acid gas as a lift gas into a crude oil production well traversing the formation.

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2. The method of claim 1, wherein the acid gas comprises a mixture of produced gas and an acid gas from a natural or industrial source.

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3. The method of claim 1, wherein the first fraction is injected slugwise into the formation, and injection of acid gas slugs is alternated by injection of water slugs into the formation.

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4. The method of claim 1, wherein the production tubing is tapered.

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5. The method of claim 1, wherein the lift gas is injected using a lift gas injection conduit arranged within a production tubing in the production well.

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6. The method of claim 5, wherein use is made of a concentric completion and the lift gas is injected through the inner string of this concentric completion and the produced fluids with the lift gas is produced through the annulus between the insert string and the main tubing of the concentric completion.

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7. The method of claim 1, wherein a conventional downhole safety valve is set below the bottom of the insert string of the concentric completion and above the production packer.

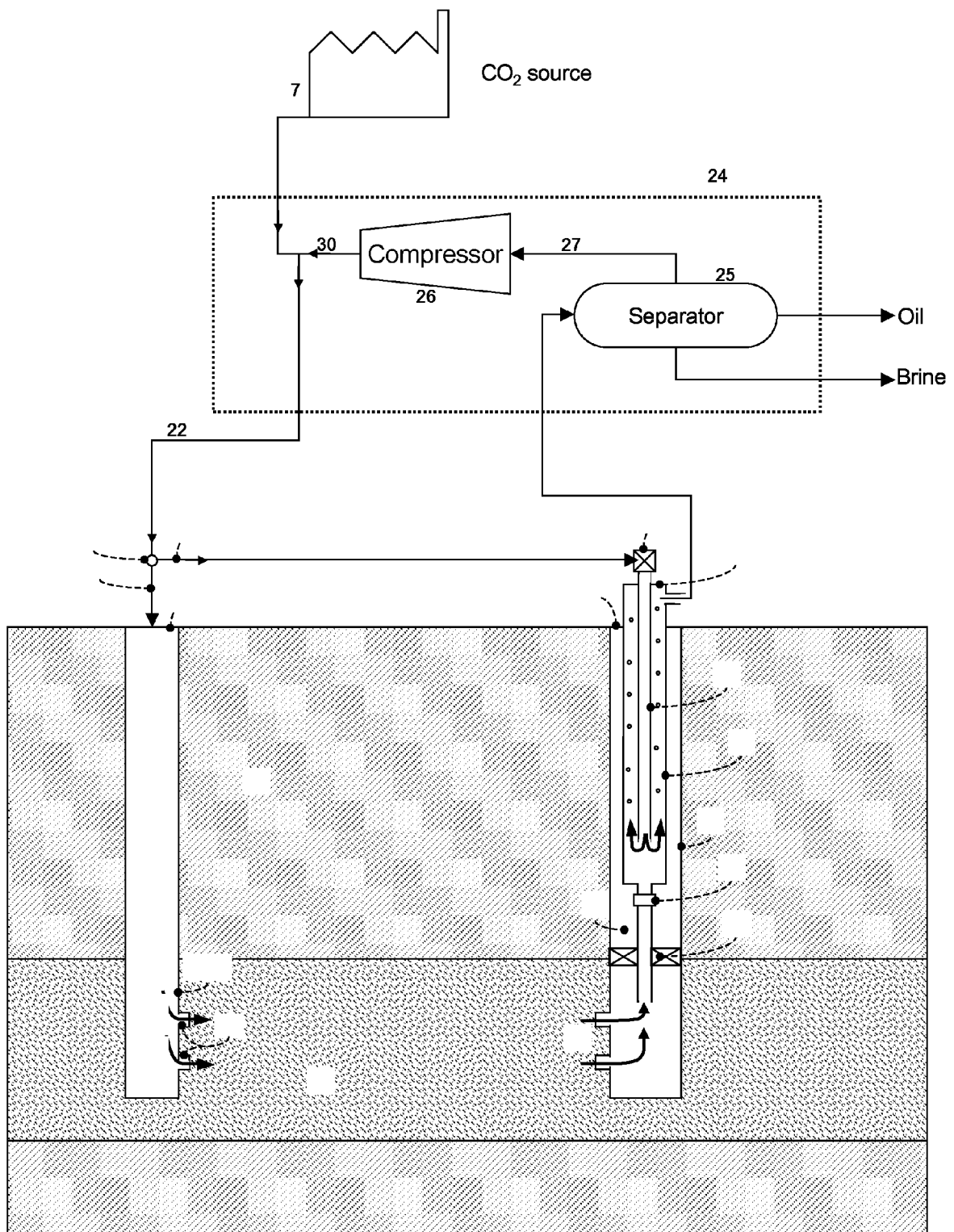
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8. The method of claim 1, wherein the available volume of acid gas comprises acid gas obtained from a natural or industrial acid gas source and the first fraction is injected into the formation through an acid gas injection well traversing the formation at a distance from the production well such that the first fraction mixes with and displaces crude oil within the pores of the formation and flows towards the production well.

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9. The method of claim 4, wherein at least some acid gas of the first fraction is produced through the production tubing and at least part of the first and/or second fraction is recycled into the available volume of acid gas.

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10. The method of any preceding claim, wherein the rate and/or pressure at which the second fraction is injected into the acid gas injection conduit is adjusted on the basis of one or more of the following parameters:

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 - target and/or fluctuation of crude oil production of the production well(s);
 - density and/or watercut of the well effluents in the production tubing of the production well(s);
 - available acid gas volume and/or acid gas compressor capacity;
 - bottom hole pressure in the production well.
11. The method of claim 10, wherein the rate and/or pressure at which the second fraction is injected into the acid gas injection conduit is adjusted in relation to bottom hole pressure in the production well such that injection of the second fraction into the formation is inhibited.
12. The method of claim 1, whereby the injected acid gas comprises significant mole fractions of H₂S and CO₂.





EUROPEAN SEARCH REPORT

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EP 09 15 6550

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Place of search The Hague		Date of completion of the search 21 August 2009	Examiner van Berlo, André
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EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

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