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(54) **Method and system for enhancing natural gas production**

(57) A Nitrogen Assisted Depletion Drive (NADD) for enhancing natural gas production from an underground natural gas containing formation (20,30), such as a dry, wet and/or tight gas reservoir, comprises injecting non-corrosive Nitrogen (N₂) containing drive gas into the for-

mation (20,30) via at least one injection well (22, 31A-D) during a period of at least several months, thereby enhancing natural gas production and reservoir pressure whilst inhibiting corrosion of corrosion prone production facilities and inhibiting subsidence of the overburden.

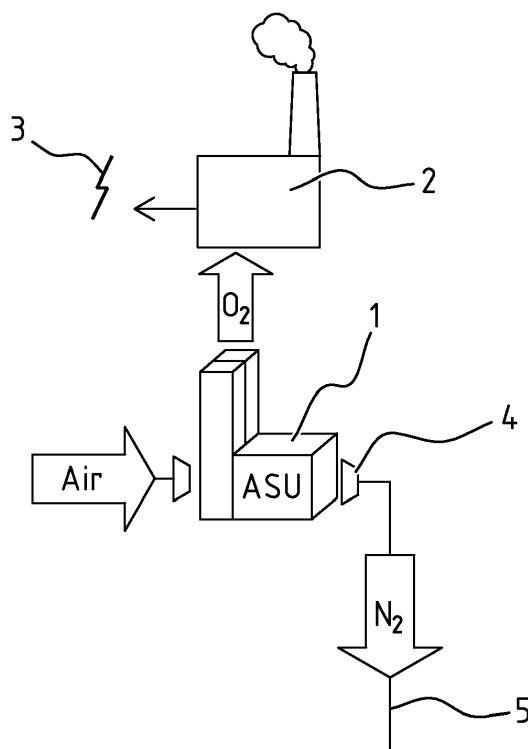


FIG. 1

Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method and system for enhancing natural gas production from an underground natural gas containing formation.

[0002] The formation may be a natural gas reservoir, which may be partially depleted, a tight gas reservoir in which natural gas is present in pores of a substantially impermeable formation, a water reservoir containing residual natural gas or a capped permeable formation into which natural gas is injected for storage and use during peak periods of natural gas consumption.

[0003] US patent 4,765,407 discloses a method for enhancing production of gas condensates from a gas condensate reservoir by injecting a mixture of carbon dioxide and nitrogen obtained from a Claus plant into the reservoir. A disadvantage of this known injection technology is that a mixture of carbon dioxide and nitrogen is corrosive and will induce corrosion of corrosion prone fluid injection and production facilities.

[0004] International patent application WO 2012021282 discloses a method for enhancing recovery of hydrocarbons trapped in a hydrate containing formation by intermittently injecting slugs of a carbon dioxide containing releasing agent and of a nitrogen containing reagent into the formation.

[0005] Canadian patent application CA 2568358 discloses a method for fracturing a hydrate or shale oil containing formation by injecting liquid nitrogen into the formation.

[0006] A limitation of the known nitrogen injection technologies is that they are either configured to enhance production from gas condensate, hydrate and/or shale oil containing formations or from tight reservoirs by fracturing and that they are not configured to enhance natural gas production from a natural gas or residual gas reservoirs by displacing gas.

[0007] There is a need for a method and system for enhancing natural gas production from a natural gas containing formation, which may be partly depleted and contain residual gas.

[0008] Furthermore there is a need for a method and system for enhancing natural gas production from a natural gas containing formation in a cost effective and safe manner by using an inert drive medium that can be generated in large quantities at low cost.

[0009] In addition there is a need for a method and system for enhancing natural gas production from a natural gas containing formation in such a manner that subsidence of the overburden is inhibited.

SUMMARY OF THE INVENTION

[0010] In accordance with the invention there is provided a method for enhancing natural gas production from an underground natural gas containing formation,

the method comprising injecting non-corrosive Nitrogen containing drive gas into the formation during a period of at least several months, during at least part of which period natural gas is produced from the formation.

[0011] The non-corrosive Nitrogen containing drive gas may be injected a) into a natural gas containing formation which is an at least partly depleted gas reservoir and which may have been invaded by water through the expansion of a connected aquifer and thereby leaving residual gas in the original gas reservoir, b) into an aquifer, which may contain residual gas below the original Free Water Level (FWL) and which is connected to a gas reservoir and c) into an aquifer containing residual gas, which it is not connected to a gas reservoir. N₂ may be injected below or above a natural fracturing pressure gradient. Fracturing here is temporary as a consequence of high injection pressure and fracturing will cease until the injection pressure is lowered or injection stops.

[0012] The permeable underground formation layer may be tilted and have an upper and a lower edge and the Nitrogen containing drive gas may be injected into the formation in the vicinity of the lower edge of the tilted permeable underground formation layer.

[0013] The natural gas containing formation may not contain a substantial amount of associated natural gas associated to crude oil, natural gas in a gas cap above an oil reservoir, crude oil and/or high amounts of retrograde condensates that drop out in the formation.

[0014] After injection of a slug of the Nitrogen containing drive gas a slug of corrosive drive gas comprising Carbon Dioxide and/or flue gases may be injected into the reservoir, wherein the slug of Nitrogen containing drive gas may have such a volume that it provides in the reservoir a barrier between the slug of corrosive drive gas and the natural gas, which barrier inhibits mixing of the corrosive drive gas with the natural gas and inhibits the corrosive drive gas to reach natural gas production wells and other natural gas production facilities during the production of natural gas via these wells and facilities.

[0015] Alternatively, after injection of a slug of the Nitrogen containing drive gas a slug of any type of other drive non-corrosive gas or gas mixture or water may be injected into the formation prior to injecting the corrosive drive gas.

[0016] In accordance with the invention there is furthermore provided a system for enhancing natural gas production from an underground natural gas containing formation, the system comprising at least one injection well through which non-corrosive Nitrogen containing drive gas is injected into the formation during a period of at least several months and at least one production well through which natural gas is produced during at least part of said period.

[0017] The Nitrogen containing drive gas may be obtained from an Air Separation Unit (ASU) that separates the air into streams of nitrogen, oxygen and/or oxygen enriched air and that supplies the oxygen and/or oxygen enriched air to an industrial plant, which may be a power

plant in which in a mixture of fuel and oxygen or oxygen enriched air is combusted to generate electrical energy and to generate flue gases which contain Carbon Dioxide that may be injected after a slug of Nitrogen containing drive gas into the formation in accordance with an optional embodiment of the method according to the invention. In such case the injected Nitrogen containing drive gas provides a barrier that inhibits corrosive drive gas containing Carbon Dioxide or any other non-inert or hazardous drive gas to reach the natural gas production facilities.

[0018] These and other features, embodiments and advantages of the method and/or system according to the invention are described in the accompanying claims, abstract and the following detailed description of non-limiting embodiments depicted in the accompanying drawings, in which description reference numerals are used which refer to corresponding reference numerals that are depicted in the drawings.

[0019] Similar reference numerals in different figures denote the same or similar objects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Figure 1 shows how Nitrogen for use in the method according to the invention is separated from oxygen in an Air Separation Unit(ASU);

Figure 2A schematically shows how production of Natural Gas is enhanced by one embodiment of the Nitrogen Assisted Depletion Drive (NADD)method according to the invention;

Figure 2B schematically shows how production of Natural Gas is enhanced by another embodiment of the Nitrogen Assisted Depletion Drive (NADD)in combination with the Nitrogen Enhanced Residual Gas (NERG) method according to the invention;

Figure 2C schematically shows how production of Natural Gas is enhanced by a yet another embodiment of the combination of the Nitrogen Assisted Depletion Drive (NADD) and the Nitrogen Enhanced Residual Gas (NERG)method according to the invention;

Figure 2D schematically shows how production of Natural Gas is enhanced by a further embodiment of the Nitrogen Enhanced Residual Gas (NERG) method according to the invention; and

Figure 3 schematically shows how production of Natural Gas is enhanced in a tight gas reservoir by yet a further embodiment of either the Nitrogen Assisted Depletion Drive (NADD) or the Nitrogen Enhanced Residual Gas (NERG) method according to the invention.

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENTS

[0021] Figure 1 shows how Nitrogen (N_2) is separated from oxygen (O_2) in an Air Separation Unit(ASU)(1) of a power plant (2) that generates electrical energy (3) by combusting fuel using Oxygen(O_2) or an Oxygen enriched air mixture. The generated Nitrogen (N_2) is subsequently pumped by a compressor (4) into a nitrogen supply conduit (5) that is connected to one or more Nitrogen injections wells 22, 31A-D as shown in Figures 2A-D and 3.

[0022] Figures 2A-2D schematically show how Nitrogen (N_2) that may be generated by the ASU (1) shown in Figure 1 is injected as an inert, non-corrosive drive gas into an underground gas reservoir formation 20 to perform a Nitrogen Assisted Depletion Drive (NADD)or the Nitrogen Enhanced Residual Gas (NERG)process according to the invention.

[0023] The underground gas reservoir is located in a permeable gas bearing formation layer, also known as the reservoir formation 20, which is located underneath an impermeable cap layer 21 that traps the natural gas within the reservoir formation 20 and the Nitrogen (N_2) is injected via a Nitrogen injection well 22 into a part of the reservoir formation 20 at a distance to the production well at 20A of the reservoir formation 20 whilst natural gas (comprising CH_4 and other constituents)is produced via a natural gas production well 23.

[0024] In the embodiment shown in Figure 2A the reservoir formation 20 only comprises a minor fraction of water which is dispersed in the pores of a tilted formation layer, so that there is no water accumulation in this part of the reservoir formation 20.

[0025] In the embodiment shown in Figure 2B there is significant accumulation of water (H_2O) in the pores of near the lower edge 20A of the tilted reservoir layer, so that there is a water layer 24 having a upper water level 25 within the pores of the reservoir formation 20, but which water layer may comprise a substantial amount of natural gas.

[0026] In the embodiment shown in Figure 2B the Nitrogen (N_2) is injected into the water layer 24 to stimulate migration of natural gas (CH_4) from the water layer 24 and to enhance flux of natural gas (CH_4) through the reservoir formation 20 to the natural gas production well 23.

[0027] Figure 2C schematically shows how natural gas (CH_4) has been partly separated from the pores near the lower edge 20A of the reservoir formation 20 and pore water reaches the production well 23 leaving trapped or residual gas behind.

[0028] Figure 2D schematically shows an embodiment where the pores of substantially the entire reservoir formation 20 are filled with a water-gas mixture comprising pore water and Natural Gas (CH_4), which mixture is stimulated to flow into the production well 23 by injecting Nitrogen into the injection well 22 near the lower edge of

the reservoir formation 20.

[0029] Figure 3 schematically shows how production of Natural Gas (CH₄) from a tight gas reservoir or residual gas formation 30 is enhanced by yet another embodiment of the Nitrogen Assisted Depletion Drive (NADD) or Nitrogen Enhanced Residual Gas (NERG) process according to the invention wherein Nitrogen is injected into possibly several Nitrogen injection wells 31A-D and natural gas (CH₄) is produced via possibly several production wells 32A-D traversing the tight gas formation 30.

Claims

1. A method for enhancing natural gas production from an underground natural gas containing formation, the method comprising injecting a non-corrosive Nitrogen containing drive gas into the formation during a period of at least several months, during at least part of which period natural gas is produced from the formation.
2. The method of claim 1, wherein the drive gas is injected during a period of at least several months via an injection well into the formation at a pressure below a fracturing pressure of the formation and the natural gas is produced via a production well that traverses the formation at a selected distance from the injection well so that the drive gas drives the natural gas through the formation into the production well.
3. The method of claim 2, wherein the formation comprises residual natural gas trapped in pore water below a Free Water Level (FWL) and the Nitrogen containing drive gas is injected into the pore water below the Free Water Level (FWL) in the formation.
4. The method of claim 2 or 3, wherein the formation is a tilted formation layer with an upper and a lower edge and the Nitrogen containing drive gas is injected into the formation in the vicinity of the lower edge of the tilted permeable underground formation layer.
5. The method of any one of claim 1-4, wherein the underground natural containing formation does not contain a substantial amount of natural gas associated to crude oil, natural gas in a gas cap above an oil reservoir, crude oil and/or condensates.
6. The method of any one of claims 1-5, wherein after injection of a slug of the non-corrosive Nitrogen containing drive gas a slug of corrosive drive gas comprising Carbon Dioxide and/or flue gases is injected into the formation.
7. The method of claim 6, wherein the slug of non-corrosive Nitrogen containing drive gas has such a volume that it provides in the formation a barrier between the slug of corrosive drive gas and the natural gas, which barrier inhibits mixing of the corrosive drive gas with the natural gas and inhibits the corrosive drive gas to reach natural gas production wells and other natural gas production facilities during the production of natural gas via these wells and facilities.
8. The method of any one of claims 1-5, wherein after injection of a slug of the Nitrogen containing drive gas a slug of water is injected into the formation.
9. The method of any one of claims 1-8, wherein the Nitrogen is obtained from an Air Separation Unit(ASU) that separates the air into streams of nitrogen, oxygen and/or oxygen enriched air.
10. The method of claim 9, wherein the oxygen and/or oxygen enriched air is supplied to an industrial plant.
11. The method of claim 10, wherein the industrial plant is a power plant in which in a mixture of fuel and oxygen or oxygen enriched air is combusted to generate electrical energy.
12. The method of claims 6, 7 and 11, wherein the corrosive drive gas containing Carbon Dioxide is obtained from flue gases of the power plant.
13. A system for enhancing natural gas production from an underground natural gas containing formation, the system comprising an injection well through which non-corrosive Nitrogen containing drive gas is injected into the formation during a period of at least several months and a production well through which natural gas is produced during at least part of said period.
14. The system of claim 13, wherein the formation is an at least partly depleted underground gas reservoir located in a permeable underground formation layer and the injection well is provided with pressure control means configured to inject the non-corrosive Nitrogen containing drive gas into a lower part of the formation layer at a pressure below a fracturing pressure of the formation layer.
15. The system of claim 14, wherein the Nitrogen for the drive gas is obtained from an Air Separation Unit(ASU) that separates the air into streams of nitrogen, oxygen and/or oxygen enriched air.

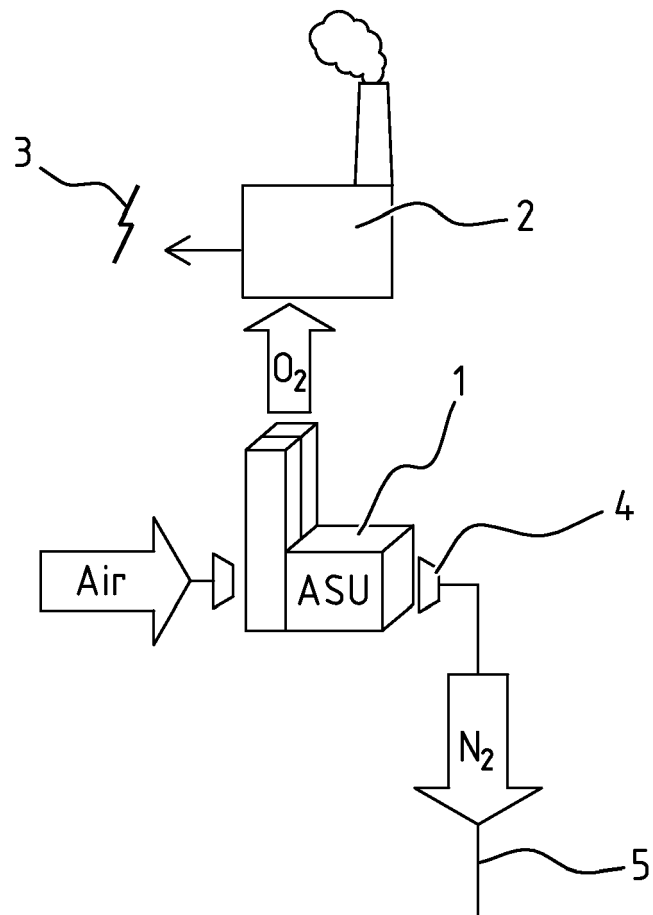
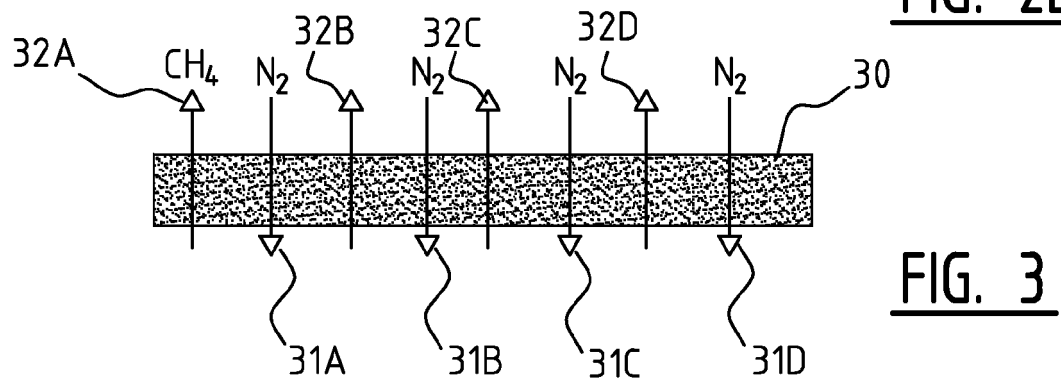
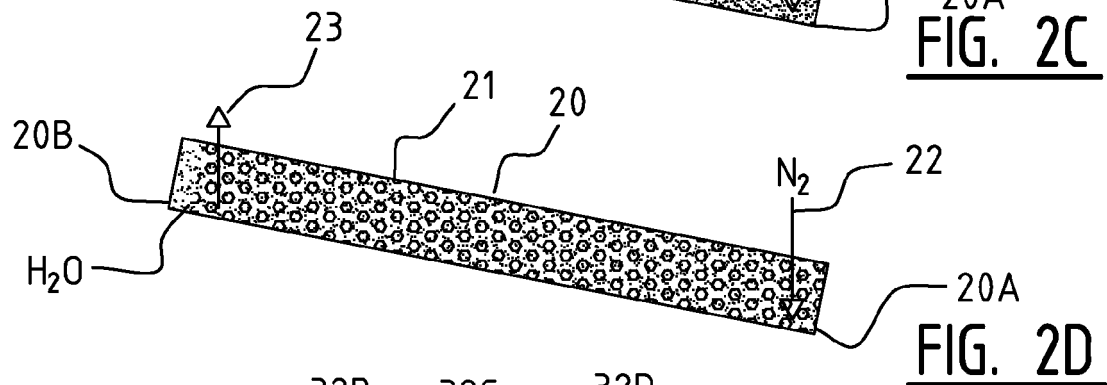
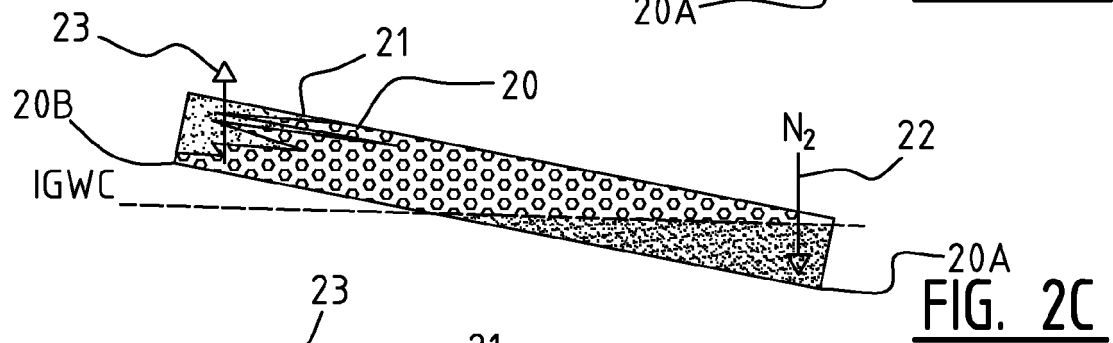
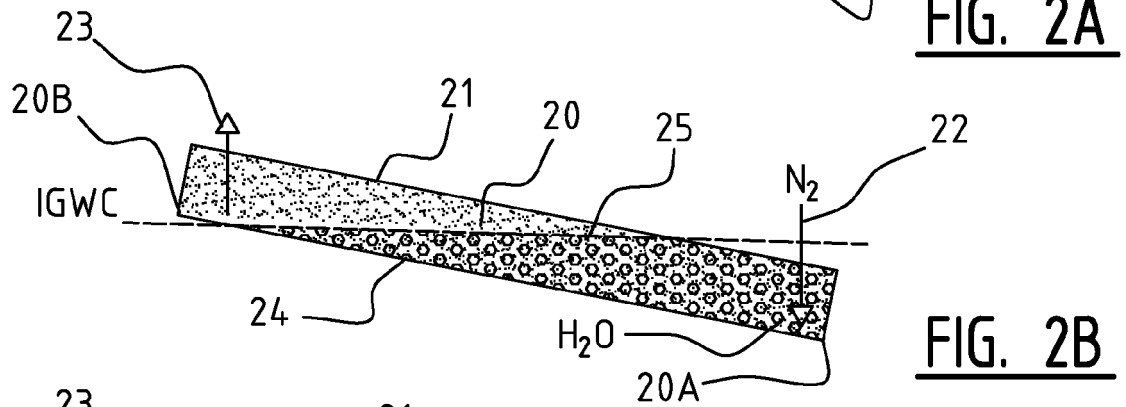
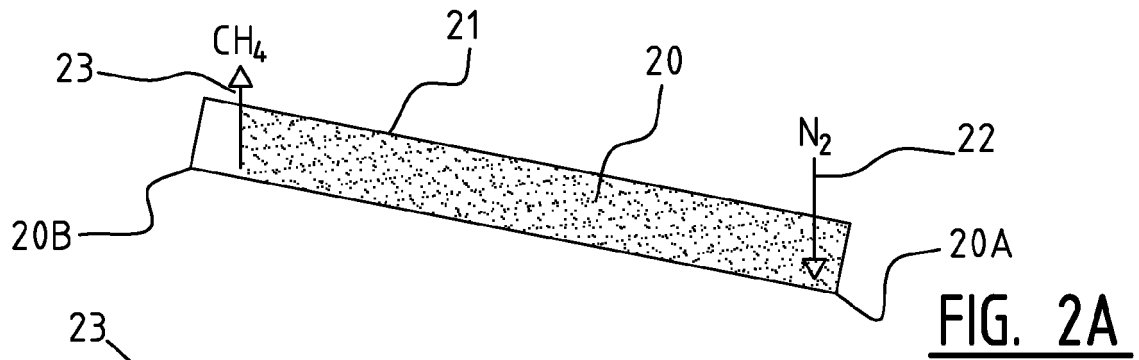


FIG. 1





EUROPEAN SEARCH REPORT

Application Number
EP 12 19 4472

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 17 May 2013	Examiner Rampelmann, Klaus
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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