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(54) **Enhancing natural gas production using nitrogen generated by an air separation unit of an industrial plant**

(57) Nitrogen generated as a by-product of an Air Separation Unit (ASU) of a power or other industrial plant operated with oxygen enriched air is used in a Nitrogen Assisted Depletion Drive (NADD) for enhancing natural

gas production from an underground natural gas containing formation (20,30), thereby reducing capital and operating cost of the NADD.

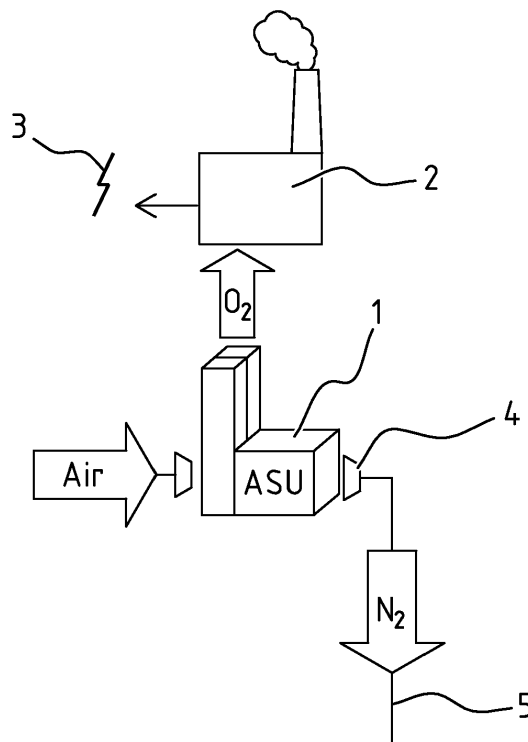


FIG. 1

Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method and system for enhancing natural gas production from an underground natural containing formation using Nitrogen(N₂) generated by an Air Separation Unit(ASU) of an industrial plant.

[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 inject a large volume of a non-corrosive Nitrogen containing drive gas into a formation to enhance natural gas production from the formation.

[0007] A further limitation of the known nitrogen injection technologies is that generation of Nitrogen in Air Separation Units(ASUs) or other available Nitrogen generation devices is expensive.

[0008] There is a need for a cost efficient method and system for cost-effective production of large quantities of Nitrogen to generate large quantities of a non-corrosive drive gas for enhancing natural gas production from a natural gas containing formation, for preserving pressure in the formation and for inhibiting subsidence of the overburden.

SUMMARY OF THE INVENTION

[0009] 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 into the formation Nitrogen generated by an Air Separation Unit(ASU) of an industrial plant operated with oxygen or oxygen enriched air.

[0010] The use of Nitrogen generated as a by-product of an ASU of an industrial plant operated with oxygen enriched air significantly reduces capital and operating cost of the Nitrogen injection into the natural gas containing formation. This implies that there is an unexpected synergy between the operations of the industrial plant operated with oxygen or oxygen enriched air and the Nitrogen injection for the Nitrogen Assisted Depletion Drive(NADD) according to the invention.

[0011] The industrial plant may be a power plant in which a mixture of fuel oxygen enriched air generated by the ASU is combusted to generate electrical energy.

[0012] Alternatively the industrial plant may be a Gas To Liquids(GTL) or chemical plant with an Air Separation Unit(ASU) for generating oxygen for use in the GTL or chemical plant.

[0013] Both in GTL and chemical plants and in oxygen enriched power plants Nitrogen generated by the ASU is a by-product, which is usually vented into the atmosphere as a waste product.

[0014] Optionally a slug of corrosive drive containing Carbon Dioxide obtained from flue gases of the industrial plant may be injected into the formation after injection of a slug of the Nitrogen, which provides a non-corrosive inert drive gas.

[0015] The subsequent injection of corrosive drive gas containing Carbon Dioxide obtained from flue gases of the industrial plant further reduces capital and operating cost of the enhanced natural gas production, wherein the injection of a non-corrosive Nitrogen containing drive gas before injection of corrosive Carbon Dioxide containing drive gas generates a barrier that inhibits contact of corrosive drive gas with corrosion prone natural gas production facilities, such as equipment in the natural gas production wells and/or other natural gas production and/or processing equipment.

[0016] 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.

[0017] Similar reference numerals in different figures denote the same or similar objects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

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 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

[0019] 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.

[0020] 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 injection wells 22, 31A-D as shown in Figures 2A-D and 3.

[0021] Figures 2A-2D schematically show how Nitrogen (N_2) that may be generated by the ASU (1) shown in Figure 1 is injected into an underground gas reservoir 20 to perform a Nitrogen Assisted Depletion Drive (NADD) or the Nitrogen Enhanced Residual Gas (NERG)method according to the invention.

[0022] The underground gas containing reservoir is formed by a tilted permeable gas bearing formation layer, also known as the reservoir formation 20, which is located underneath an impermeable gas cap layer 21.

[0023] 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 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 the reservoir layer, so that there is no water accumulation in this part

of the reservoir.

[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 reservoir formation 20, 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 (CH_4) from a tight gas reservoir or residual gas formation 30 with low permeability 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 (CH_4) 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 into the formation Nitrogen generated by an Air Separation Unit(ASU) of an industrial plant operated with oxygen or oxygen enriched air.
2. The method of claim 1, wherein the industrial plant is a power plant in which a mixture of fuel oxygen enriched air generated by the ASU is combusted to generate electrical energy.
3. The method of claim 2, wherein a slug of corrosive drive gas containing Carbon Dioxide obtained from flue gases of the power plant is injected into the formation after injection of a slug of the Nitrogen.
4. The method of claim 3, wherein the slug of Nitrogen

has such a volume that it provides in the formation a barrier between the slug of corrosive drive gas comprising Carbon Dioxide and other the natural gas, which barrier inhibits mixing of the Carbon Dioxide with the natural gas and inhibits the Carbon Dioxide to reach natural gas production facilities.

5. The method of claim 1 or 2, wherein the Nitrogen(N_2) is injected into the formation during a period of at least several months, during at least part of which period the natural gas is produced from the formation.
6. The method of claim 5, wherein the Nitrogen is injected at a pressure below a fracturing pressure of the formation.
7. The method of claim 6, wherein the formation comprises residual natural gas trapped in pore water below a Free Water Level (FWL) and the Nitrogen is injected into the pore water below the Free Water Level (FWL) in the formation.
8. The method of claim 6 or 7, wherein formation is formed by a tilted permeable formation layer with an upper and a lower edge and the Nitrogen is injected into the formation in the vicinity of the lower edge of the tilted permeable underground formation layer.
9. The method of any one of claim 1-8, wherein the formation does not contain a substantial amount of associated natural gas formed by natural gas associated to crude oil, natural gas in a gas cap above an oil reservoir, crude oil and/or condensates.
10. The method of any one of claims 1-9, wherein after injection of a slug of the Nitrogen a slug of water is injected into the formation.
11. A system for enhancing natural gas production from an underground natural gas containing formation, the system comprising:
 - an injection well configured to inject Nitrogen into the formation during a period of at least several months;
 - a production well configured to produce natural gas during at least part of said period;
 - an industrial plant operated with oxygen enriched air obtained from an Air Separation Unit(ASU) which is configured to separate air into streams of the Nitrogen and the oxygen enriched air.
12. The system of claim 11, wherein the industrial plant is a power plant configured to combust a mixture of fuel and oxygen enriched air generated by the ASU to generate electrical energy.
13. The method of claim 12, wherein the injection well is configured to inject subsequent slugs of the Nitrogen and Carbon Dioxide(CO_2), which CO_2 is obtained from flue gases of the power plant.

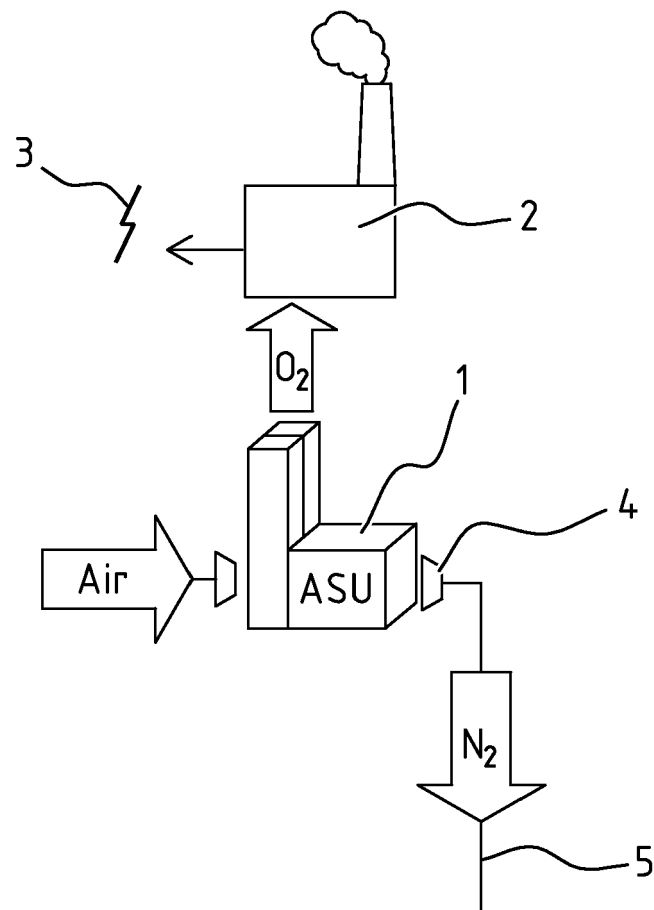
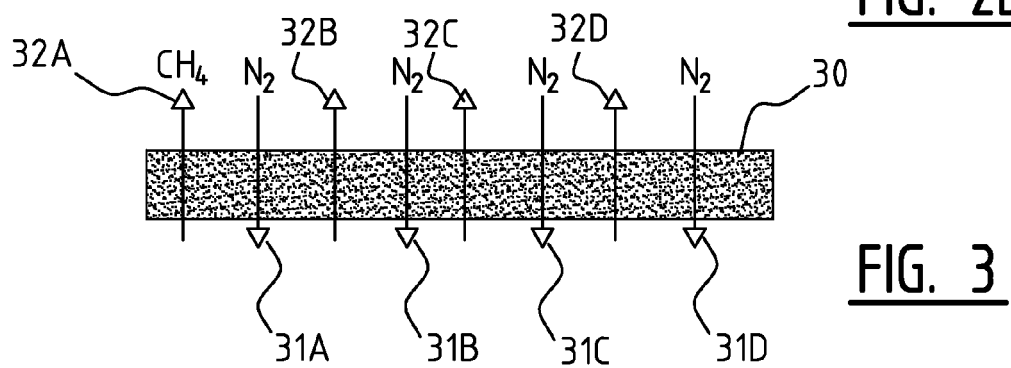
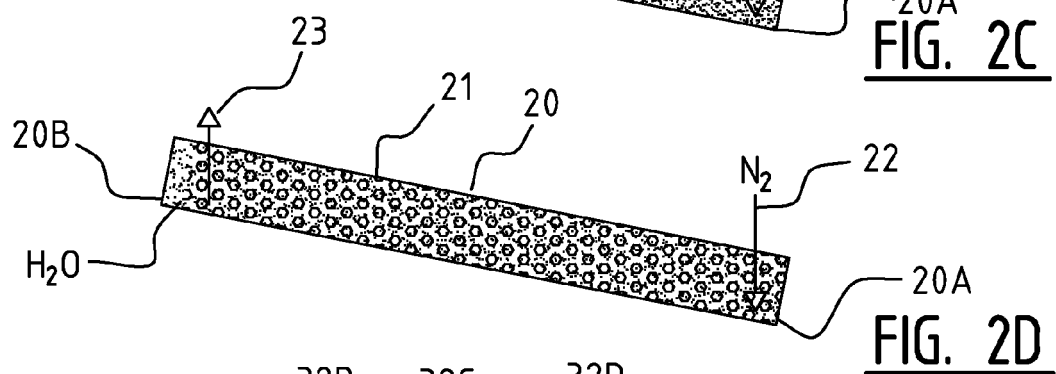
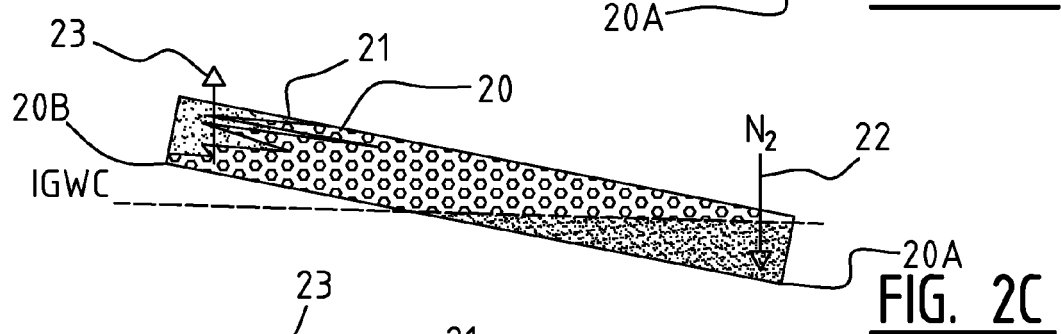
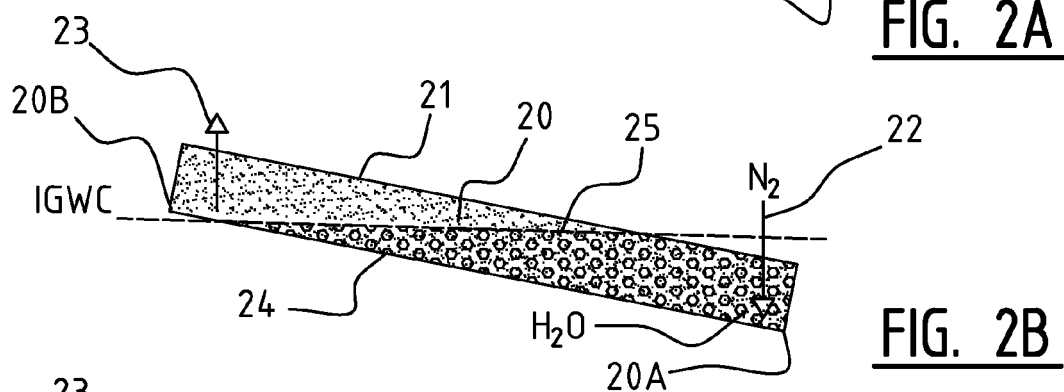
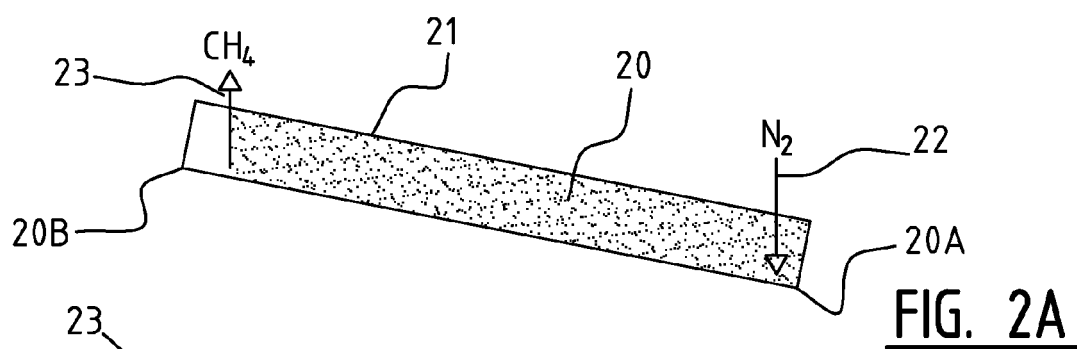


FIG. 1





EUROPEAN SEARCH REPORT

Application Number
EP 12 19 4474

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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
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503.03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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