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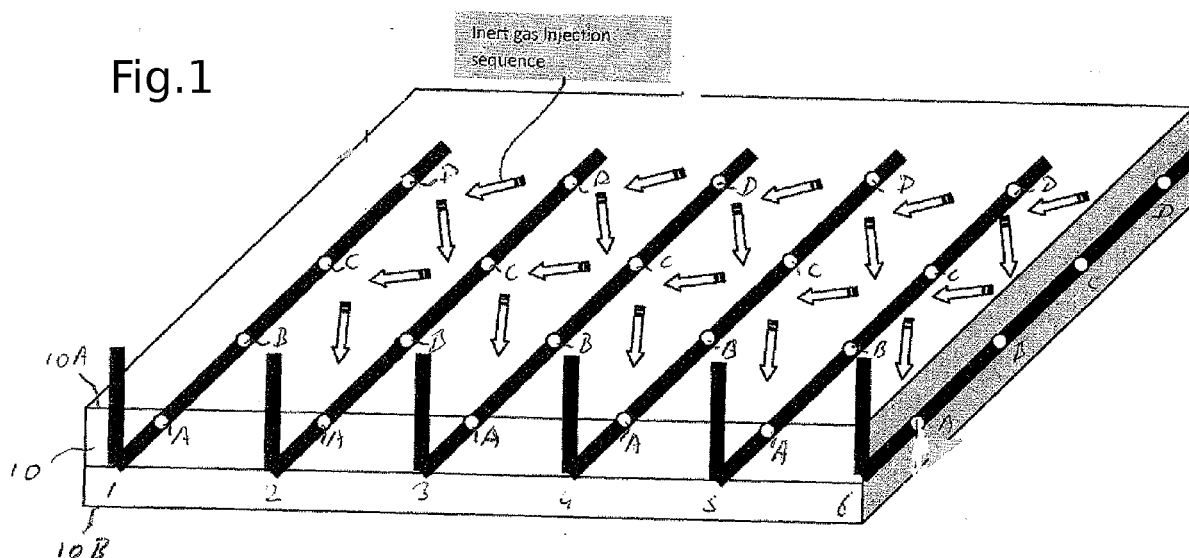
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(54) **Method for induced fracturing in a subsurface formation**

(57) A method of induced fracturing of a subsurface formation (10) comprises sequentially injecting at least partly liquefied inert fluid slugs through an array of injection wells (1-6, 11-20) into different parts of the formation

(10) such that the formation initially freezes and contracts and subsequently expands due to the evaporation of the inert fluid, thereby enhancing the induced fracturing process.



Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method for induced fracturing in a subsurface formation.

[0002] Methods for fracturing a subsurface formation by injecting a fluid that generates fractures in the formation are known from US patents 3,664,422; 3,581,821; 3,759,329; 3,842,910; 7,198,107; 7,264,049; 7,416,022; 7,516,784; 7,784,545 and 7,823,644, from US patent applications US20060243437; US20060065400; US20040214728; US20080190606; US20100270038; US2010/005/272 and US2012/203072, from Canadian patents CA2639539, CA2644169, from International patent applications W09618801; W0201025540; W02009147394; W02009138735; W02007988606 and W0200798370, and from UK patents GB2302108 and GB2329662.

[0003] In conventional fracturing methods large amounts of proppant and water-based fluids with chemical additives are injected, at very high rates, into the formation.

[0004] The traditional water-based fracturing fluids generally can comprise any combination of slickwater, gelled polymer, crosslinkers and gelled LPG mixed with proppants and chemical additives.

[0005] The use of chemical additives has created global controversies regarding the chemicals used in natural gas extraction and claimed negative impact of the hydraulic process on drinking water quality from nearby aquifers. There is a need for an induced fracturing method that requires a reduced amount or no water, proppants or chemical additives and that has less potential of negative impact on drinking water quality from nearby aquifers.

SUMMARY OF THE INVENTION

[0006] In accordance with the invention there is provided a method of induced fracturing of a subsurface formation, the method comprising sequentially injecting at least partly liquefied inert fluid slugs into different parts of the formation.

[0007] The formation may comprise a hydrocarbon fluid, such as a natural gas containing tight gas formation, a shale gas formation or a Coal Bed Methane (CBM) containing formation, or any other type of hydrocarbon containing formation, and the liquefied inert fluid slugs may comprise at least one of the following inert fluids: Nitrogen(N₂), Carbon Dioxide (CO₂), Helium(He) and Liquefied Natural Gas(LNG) and each inert fluid slug may be injected in continuous or non continuous manner and comprise such an amount of inert fluid that at least a section of the formation into which the slug is injected suffers a thermal differential such that it thereby contracts. This formation will subsequently reheat the initial inert fluid slug at least partly evaporating and expanding

the gas and thereby generating further induced fractures in the formation.

[0008] As an additional option to the patented technique, after an initial inert fluid slug is injected continuously or non continuously into a first section of the formation a subsequent inert slug may be injected into a second section of the formation, which is located adjacent to the first section and the time interval between injecting the initial and subsequent slugs may be selected such that, at the time when the subsequent inert fluid slug is injected into the second part of the formation and induces at least part of the second section to again suffer a thermal differential and contract, the first section has been heated up by the surrounding formation to such a temperature that the initial inert fluid slug at least partly evaporates and expands and thereby generates further induced fractures in the first section of the formation, wherein the simultaneous expansion of the first section and contraction of the second section enhances the fracturing process.

[0009] These and other features, embodiments and advantages of the method and 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. Similar reference numerals in different figures denote the same or similar objects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Figure 1 is a schematic three-dimensional view of a subsurface formation penetrated by segmented lower sections of six inert fluid injection wells; Figure 2 is a cross-sectional view of a subsurface formation penetrated by segmented lower sections of ten staggered fluid injection wells; and Figure 3 is a longitudinal sectional view of the segmented lower section of five of the staggered fluid injection wells shown in Figure 2.

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENTS

[0011] Figure 1 depicts a schematic three-dimensional view of a subsurface formation 10 having a substantially horizontal upper and lower boundaries 10A and 10B, which formation 10 is penetrated by substantially horizontal segmented lower sections 1A-D,..., 6A-6D of six inert fluid injection wells 1-6. Each well 1-6 comprises a segmented lower section 1A-1D, ..., 6A-6D that is divided by valves or other isolation devices into four segments A-D.

[0012] The valves or other isolation devices sequentially permit injection of an at least partly liquefied inert

fluid slug comprising Nitrogen, Carbon Dioxide, Helium and/or Liquefied Natural Gas (LNG) in a continuous or non continuous manner through one or more well segments 1A-D,..., 6A-6D, which have perforations that permit fluid to liquefied inert fluid to flow into and thereby initially freeze and contract and to subsequently evaporate and expand in the surrounding formation 10, wherein the contraction and subsequent expansion enhances the induced fracturing process without requiring added chemicals. A suitable sequence of opening and closing well segments is 2D->1D, 1D->2C, 2C->1C, 1C->2B, 2B->1B, 1B->2A, 2A->1A, 1A->3D, 3D->2D, 2D->3C, 3C->2C, 2C->3B, 3B->2B, 2B->3A, 3A->2A, 2A->4D, 4D->3D, 3D->4C, 4C->3C, 3C->4B, 4B->3B, 3B->4A, 4A->3A, 3A->5D, ... until each of the infinitive number of horizontal well segments has been opened and subsequently closed.

[0013] It will be understood that instead of using six inert fluid injection wells 1-6 which each have four substantially horizontal segmented lower section 1A-D,..., 6A-6D as shown in Figure 1 any other number of inert fluid injection wells and any other number (n) of segmented lower sections and valves or other isolation devices may be used.

[0014] Figure 2 is a cross-sectional view of a tight gas, shale gas or Coal Bed Methane(CBM) containing formation 10, or any other type of hydrocarbons containing formation having an substantially horizontal upper and lower boundaries 10A and 10B, which formation is penetrated by horizontal lower sections 11-20 of nine inert fluid injection wells.

[0015] The lower sections 11-20 are staggered, such that the lower sections 12, 14, 16, 18 and 20 are located closer to the upper boundary 10A than to the lower boundary 10B, whereas the lower sections 11, 13, 15, 17 and 19 are located closer to the lower boundary 10B than to the upper boundary 10A.

[0016] Figure 3 is a schematic top view of the formation 10 of Figure 2 which shows the lower sections of five wells 12-16 out of the series of nine wells 11-20 shown in Figure 2. Each of these lower sections comprises a suitable number of segments A,B,C,... Z, etc., wherein the number may be in the order of tens or hundreds that are separated by valves and/or other isolation devices.

[0017] The staggered arrangement of the lower sections of the inert fluid injection wells 11-20 shown in Figures 2 and 3 further enhances the induced fracturing process, so that the formation 10 can be induce fractured by physical and thermodynamic effects initiated by the initial contraction and subsequent expansion of the inert fluids and formation 10 and the induced fracturing associated with the injection of cold substantially liquid inert fluid, which then evaporates in the pores of the formation 10 thereby inducing fracturing in the formation 10 without requiring any or any substantial amount of additional chemicals that could lead to potential causes of pollution of aquifers adjacent to formation 10 and/or the inert fluid injection wells 1-6 and 11-20.

Claims

1. A method of Induced fracturing of a subsurface formation, the method comprising sequentially injecting at least partly liquefied inert fluid slugs into different parts of the formation.
2. The method of claim 1, wherein the at least partly liquefied inert fluid slugs comprise at least one of the following inert fluids: Nitrogen, Carbon Dioxide, Helium and Liquefied Natural Gas.
3. The method of claim 2, wherein each inert fluid slug comprises such an amount of inert fluid that at least a section of the formation into which the slug is injected freezes and thereby contracts.
4. The method of claim 3, wherein after an initial inert fluid slug is injected into a first section of the formation a subsequent inert slug is injected into a second section of the formation, which is located adjacent or nearby to the first section.
5. The method of claim 4, wherein the time interval between injecting the initial and subsequent slugs is selected such that, at the time when the subsequent inert fluid slug is injected into the second part of the formation and induces at least part of the second section to freeze and contract, the first section has been heated up to such a temperature that the initial inert fluid slug at least partly evaporates and expands and thereby generates fractures in the first section of the formation.
6. The method of claim 5, wherein the simultaneous expansion of the first section and contraction of the second section enhances the fracturing process.
7. The method of any one of claims 1-6, wherein the subsurface formation comprises a hydrocarbon fluid, which is induced to flow from the fractured formation to hydrocarbon fluid production facilities at the earth surface after completion of the fracturing method.
8. The method of claim 7, wherein the subsurface formation has an upper and a lower boundary and is penetrated by a plurality of inert fluid injection wells.
9. The method of claim 8, wherein at least two of the fluid injection wells each have a lower section that extends substantially parallel to the lower section of another fluid injection well and to the lower and/or lower boundary of the subsurface formation.
10. The method of claim 9, wherein at least two of the fluid injection wells each have a lower section that is divided into a plurality of longitudinally spaced segments that are separated by a valve system that per-

mits inert fluid to flow from one segment into the formation, whilst blocking fluid flow from each other segment into the formation.

11. The method of claim 9 or 10, wherein the lower section of at least one fluid injection well is located at a smaller average distance from the upper boundary than the lower section of at least one other fluid injection well. 5
- 10
12. The method of claim 11, wherein the formation is penetrated by at least four inert fluid injection wells having staggered lower sections that are alternately located at a smaller average distance from the upper boundary than from the lower boundary and at a smaller average distance from the lower boundary than from the upper boundary. 15
13. The method of any one of claims 7-12, wherein the formation is a shale gas formation, a tight gas formation or a formation comprising coal bed methane. 20
14. The method of any one of claims 7-13, wherein the inert fluid injection wells are configured to initially inject a sequence of inert fluid slugs adjacent to one lateral boundary of the formation and to gradually migrate the injection of subsequent sequences of inert fluid slugs towards an opposite lateral boundary of the formation. 25

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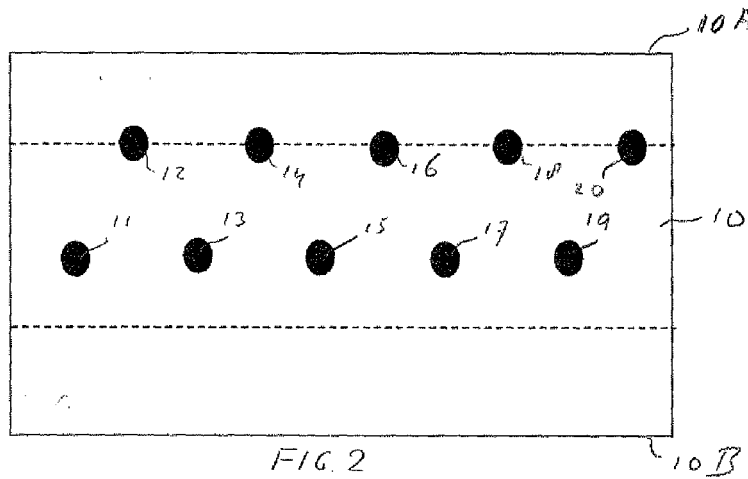
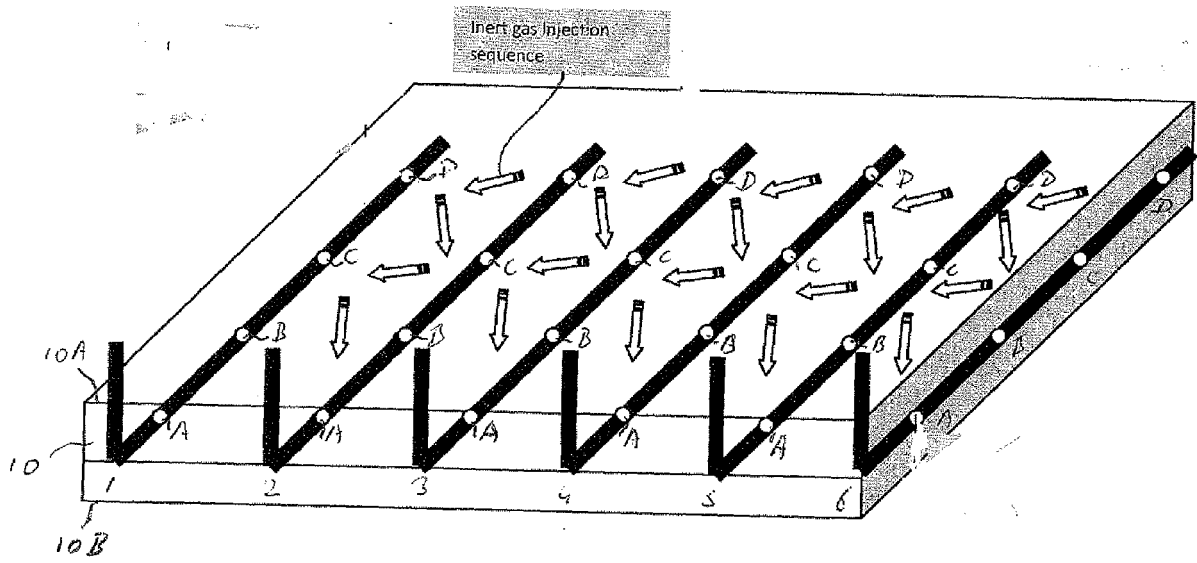


FIG. 2

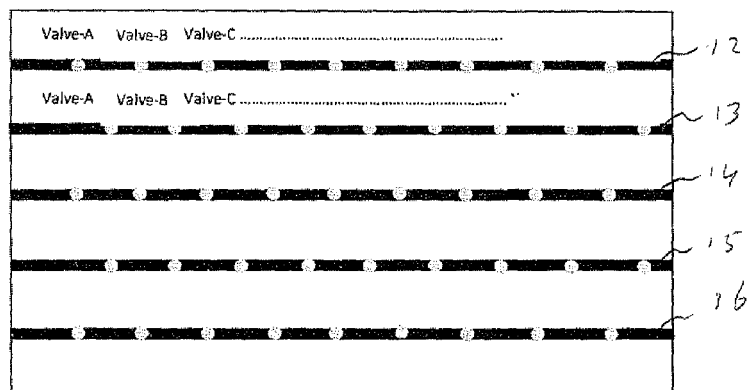


FIG. 3



EUROPEAN SEARCH REPORT

Application Number
EP 11 16 7877

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CA 2 568 358 A1 (MAGUIRE JAMES Q [US]) 17 May 2008 (2008-05-17) * paragraph [0013] - paragraph [0035]; figures 1, 2 *	1-14	INV. E21B36/00 E21B43/26
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			TECHNICAL FIELDS SEARCHED (IPC)
			E21B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 September 2011	Examiner Ott, Stéphane
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
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 16 7877

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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29-09-2011

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