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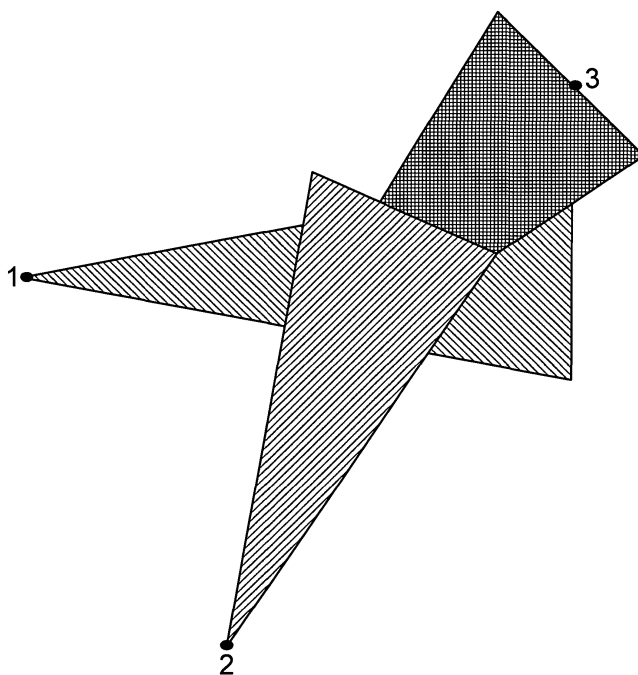
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(54) Method for the methane recovery from coal

(57) The invention describes a process for the recovery of methane contained in a coal seam, wherein a fluid is injected into coal seam via the two injection wells 1 and 2. Both injection wells 1 and 2 are located at approximately the same distance from the production well 3. The driving gas flow G1 is injected into the coal seam from the injection well 1 in a pulsed manner. The driving gas flow G2 is also introduced into the coal seam from the injection well 2 in a pulsed manner. Pulse durations of approx. 20 min are used thereby. The time lag between

two pulses of an injection is approx. 1 hour. The injected gas quantities G1 and G2 are thereby in the same magnitude in each case. Due to the overlap of the positioned and pulsed driving gas flows G1 and G2, a resulting gas flow G3 forms, which moves in the direction of the production well 3. The methane is thus driven in the direction of the production well 3 by means of the positioned and pulsed driving gas flows. In this embodiment of the invention, nitrogen and carbon dioxide are injected so as to alternate, so that the different characteristics of both gases can be used for the coal bed methane recovery.

Figure 1

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Description

[0001] The invention is related to a process for the recovery of methane stored in a coal seam, whereby a driving fluid is injected through at least one injection well into the coal seam, and whereby the desorbed products including methane are recovered by at least one production well.

[0002] Within the scope of this application an injection well is an essentially vertical pipe in the ground into which water, other liquids, or gases are pumped or allowed to flow. Correspondingly a production well is an essentially vertical pipe in the ground through which product gases or liquids are lifted to the surface.

[0003] Coal seams usually contain methane adsorbed on the solid matrix of the coal. The presence of this gas is well known from its occurrence in underground coal mining, where it presents a serious safety risk. Such kind of methane is usually called coalbed methane, often referred to as CBM, or 'sweet gas' because of its lack of hydrogen sulfide is distinct from a typical sandstone or other conventional gas reservoir, as the methane is stored within the coal by an adsorption process. The methane is in a near-liquid state, lining the inside of pores within the coal (called the matrix). The open fractures in the coal (called the cleats) can also contain free gas or can be saturated with water.

[0004] Unlike much natural gas from conventional reservoirs, coalbed methane contains very little heavier hydrocarbons such as propane or butane, and no natural gas condensate. It often contains up to a few percent carbon dioxide. Usually such coalbed methane consists of mainly methane and trace quantities of ethane, nitrogen, carbon dioxide and few other gases.

[0005] According to the state of the art the adsorbed methane could be recovered. The methane is released when the coal seam is depressurised. To economically retrieve reserves of methane, wells are drilled into the coal seam, the seam is dewatered, then the methane is extracted from the seam, compressed and piped to market. The goal is to decrease the water pressure by pumping water from the well. The decrease in pressure allows methane to desorb from the coal and flow as a gas up the well to the surface.

[0006] Another known method is the use of a driving fluid, which is injected into the coal seam by an injection well. This decreases the partial pressure of the methane which leads to an increased desorption of methane, or displaces the methane due to better adsorption properties of the injected fluid in comparison to methane. The desorbed methane could be recovered to the surface through a production well. According to the state of the art the injection of the driving fluid into the coal seam thereby usually takes place via horizontal holes in the wall of the injection well, which are distributed across the entire periphery of the line. The driving fluid is thus pressed out of the injection well so as to be distributed in all spatial directions in a spherically even manner.

[0007] The present invention is thus based on the objective of embodying a process for the recovery of methane stored in a coal seam of the afore-mentioned type in such a manner that the needed amount of the driving fluid is reduced.

[0008] The present objective is achieved by a process for the recovery of methane contained in a coal seam with the features as listed in claim 1. Advantageous embodiments of the invention are listed in the dependent claims of the present application.

[0009] According to the present invention the driving fluid is pressed out of the vertical injection well into the coal seam under pressure in a positioned and directed manner under pressure and the driving fluid is pressed out of the vertical injection well into the coal seam via at least one horizontal outlet means in the wall of the vertical injection well.

[0010] The basic idea of the invention is the use of simple outlet means in or at the wall of the vertical injection well to introduce the driving fluid in a directed and positioned manner into the coal seam. The directed and positioned injection of the driving fluid according to the invention creates a rather finger-shaped expansion front of the driving fluid. Such outlet means could be simple openings or any other kind of means which are suitable for a more or less horizontal injection of the driving fluid into the coal seam. The simplest possibility for ensuring a positioned press-in in terms of the invention are one-sided holes in the injection well, that is, the injection well encompasses holes for the driving fluid escape, which are only distributed across a part of the periphery, maximally across half of the periphery.

[0011] Within the scope of this invention, an escape of the driving fluid in a positioned manner refers to the flow of the largest part of the driving fluid along a preferred axis. Contrary thereto, an escape, in the case of which the driving fluid quantity flows in a solid angle of 360° so as to be uniformly distributed, that is, when it flows out of the injection well in all directions of space in a uniform manner, is an undirected escape. In the case of an escape in a directed and positioned manner in terms of the invention, the fluid immediately around the segment of the injection well from which the fluid escapes is not uniformly distributed in an imaginary cone volume, but mainly within a certain solid angle of 180° at most. In the case of such an escape in a positioned manner, the flowing fluid is limited at least within a hemispherical segment, but for the most part within a cone segment within an imaginary sphere volume around the injection well.

[0012] The driving fluid is not equally distributed around the injection well. The driving fluid is pressed out of the injection well in a defined directed and positioned manner. Therefore the needed amount of driving fluid could be minimised. The directed and positioned injection enables a directed stream of the driving fluid in the coal seam and allows the desorption of methane from specific, predetermined volumes of the coal seam.

[0013] In the state of the art, the driving fluid is simply

pressed out of injection well in an undirected manner into the surrounding coal seam via holes, which are uniformly distributed across the periphery of the line. Due to the large pressure difference between the injection well for the fluid supply and the surrounding rock, it is assumed that the driving fluid expands from the injection well into the surroundings in a spherical and uniformly distributed manner. However, tests in practice reveal that this is not the case. A uniform expansion of the fluid from the injection well in all directions of space requires the geological surrounding of the injection well to have approximately the same conditions. However, this is not the case in most of the coal seams.

[0014] Surprisingly, it became apparent that the directional characteristic remains in the case of the positioned escape of the driving fluid out of the well according to the invention. Due to the high pressure loss in the coal seam, one would expect that the expansion of the fluid in the coal seam would again take place in a spherical manner after only a short period of time even in the case of an escape from the injection well in a directed and positioned manner. However, new measurements reveal that this is not the case and that pressing the driving fluid into the surrounding coal seam in a positioned manner in terms of the invention also leads to an expansion of the driving fluid in the coal seam preferably in a directed and positioned manner, which also remains across greater distances of above 200 m.

[0015] As a rule, one or several injection wells are used for pressing in the driving fluid, wherein an effect is to be attained at points, such as one or several production wells, for example, which are located at a distance from one another. Pressing a fluid into a geological surrounding is thereby not necessarily successful. When using such a method for the recovery of coal bed methane, for example, an effect in terms of an increased production of methane in the production well can often only be established after several weeks and after a high consumption of fluid. In the most disadvantageous case, the driving fluid expands to a considerably improved extent in the direction away from the production well than in the direction towards the production well. According to a method of the state of the art, a large quantity of driving fluid is used in such a case, possibly without thereby attaining an increased production rate.

[0016] The effects caused by the fluid injection into a geological surrounding can be detected much earlier by means of the method according to the invention. In accordance with the method according to the invention, the driving fluid is pressed out of the injection well into the surroundings in a positioned manner. The fluid can hereby be directed and positioned to a point, where the presumed effect is to be attained, such as the production well. In this case, the fluid expands much more rapidly in the direction of the production well than in the case of a method according to the state of the art. With the same quantity of pressed-in driving fluid, a considerably higher quantity of fluid is pressed in the direction of the produc-

tion well by means of the orientation of pressing in the fluid according to the invention, than in the case of the spherical press-in according to the method of the state of the art. In accordance with the method according to the invention, the effect at a production well can thus be detected much earlier. In addition, the consumption of pressed-in fluid is reduced. This becomes evident in particular in the case of coal seams, where a sufficient quantity of the driving fluid is not available in the immediate vicinity. In the case of a positioned escape, where the fluid escapes within a hemisphere in a solid angle of 180° , the quantity of required fluid already decreases drastically. In the event that 1000 m^3 of fluid are required, for example, to attain a conveying effect in the case of the spherical escape, only 500 m^3 are required for the same effect in the case of a positioned escape.

[0017] During the recovery of methane by using a driving fluid so called fingering occurs. Fingering occurs when too much driving fluid is pressed into the coal seam at too high pressure or speed. In such a case the driving fluid breaks through to the production well without any driving effect at the desorbed methane. Since such a break-through leads to mechanical cleaning of the break-through channel the pressure drop there is lower than in the adjacent coal seam. As a result any further injected driving fluid preferably flows through this channel and therefore does not drive any methane from adjacent coal volumes. Fingering is therefore feared because it bears the risk of rendering an injection well inefficient, in extreme cases even useless. Such a common effect of the prior art could be avoided or even used as advantage by the inventive process. Due to the directed and positioned injection of the driving fluid it is even possible to revert the fingering channels by changing the injection angle in such a way, that volumes next to the fingered volumes can be treated. By pushing back methane from adjacent volumes into the fingered channels the fingering effect could be reverted to some degree. This however is possible only if the injected fluid is less prone to be adsorbed on the coal than methane.

[0018] Advantageously carbon dioxide in the gaseous or supercritical stage and/or nitrogen in the gaseous or liquid stage, are used as driving fluid. According to some special embodiments of the invention suitable micro organism are injected together with the above mentioned driving fluids into the coal seam.

[0019] When using nitrogen or carbon dioxide, the advantages of the process according to the invention become particularly apparent. Both gases must be provided and hence the gases must be transported to the coal seam. With the same effect, a considerable quantity of gas is saved with the press-in of the gases in a directed and positioned manner according to the invention. As compared to a spherical press-in in a solid angle of 360° , the press-in of the gas with a positioned cone within a solid angle of 20° only requires a gas quantity, which is less by several magnitudes. This drastically reduces the gas quantity, which leads to considerable cost savings.

[0020] In an embodiment of the invention the driving fluid is pressed out of the injection well into the coal seam via at least one horizontal outlet means designed as injection nozzle. Injection nozzles are means, which have been well-proven for establishing a fluid flow in a positioned manner.

[0021] Advantageously the pressing into the surroundings of the injection well is mainly carried out within a solid angle of 90°, preferably of 45°, particularly preferably between 10° and 30°. The smaller the solid angle, which is formed by the escaping driving fluid, the better the directive efficiency of the driving fluid. Accordingly, much more driving fluid can be introduced along a certain chosen direction in the coal seam than in the case of a spherical uniform distribution. Vice versa, considerably less driving fluid is consumed for the same effect along a certain direction of space. The reduced amount of used driving fluid has an additional advantage at the further processing of the recovered methane. The reduced amount of fluid to drive the methane to the production well leads to a reduced dilution of the recovered methane. Therefore the number of purification stages of the recovered methane could be reduced/minimised.

[0022] According to an embodiment of the invention the direction of escape of the driving fluid, preferably the angle between main axes of the injection well and direction of escape, is changed chronologically, preferably step by step. The geological factors, where the greatest desired effect is attained by means of the driving fluid supply, can be ascertained particularly quickly by means of a step by step variation of the angle between main axis of the injection well and fluid escape. It is thus furthermore possible to press the driving fluid from one injection point into the entire coal seam. The entire coal seam can thus be exploited with little effort. The number of boreholes can be reduced as compared to a method according to the state of the art. The angle is thereby preferably changed by controlling the orientation of the free moving nozzle.

[0023] Advantageously the direction of escape of the driving fluid is oriented on the structure of the rock in the surroundings, that it preferably does not deviate more than 45° from the rock structure and that it is particularly preferably oriented parallel to the rock structure.

[0024] Preferably the driving fluid is pressed in a positioned manner via two different injection wells, wherein the press-in direction of the driving fluid of the first injection well encompasses an angle to the press-in direction of the driving fluid of the second injection well. In this embodiment of the invention, with a suitable angle, it is possible to press the methane, which is driven in a direction between the production well and the second injection well by pressing in the driving fluid via the first injection well, in the direction of the production well by pressing driving fluid via the second injection well in a positioned manner.

[0025] Advantageously the driving fluid is pressed into the coal seam via a first injection well and via a second

injection well, wherein the second injection well is not located on the connecting line between the first injection well and the production well, and the driving fluid is pressed out of the second injection well in a positioned manner such that the methane is pushed in the direction of the production well.

[0026] Thereby it is preferred that the angle between press-in direction of the driving fluid out of the first injection well and the connecting line between first injection well and production well is changed in such a manner that the angle area between the connecting line of first injection well and production well and the connecting line of first injection well and second injection well is passed successively. In this embodiment of the invention, all of the methane in a triangle, which is formed by the three lines, e.g. the two injection wells and the production well, can be recovered by means of two lines for pressing in driving fluid in a positioned manner and by means of one production well. By pressing in the driving fluid out of the second injection well, the first driving fluid flow is diverted in such a manner that the methane is always pressed in the direction of the production well from each point within the triangle. Pressing in the driving fluid out of the first injection well in an arbitrary angle between the connecting lines between first injection well and production well or between first injection well and second injection well, respectively, drives the methane away from the first injection well and quasi past the production well. Due to the superimposed press-in of driving fluid out of the second injection well, this deviation, however, is again corrected in the direction of the production well.

[0027] According to another embodiment of the invention the driving fluid is pressed out in succeeding pulses. In this embodiment of the invention, the driving fluid is advantageously injected in regular pulses of predetermined length. A pulse is thereby understood to be the time period from start to stop of the injection of the driving fluid. Advantageously, several pulses of predetermined length are thereby injected consecutively. There is no fluid injection between two pulses. The velocity respectively the pressure of the fluid is roughly constant during a pulse. The injection of different driving fluids in response to succeeding pulses has also proven to be advantageous. Preferably the time lag between two injection pulses is not shorter than the length of a single pulse, preferably it is one to ten times the length of a single pulse. By means of the pulsed injection, it is attained that the size of the fluid cushion is reduced by increasing the pressure during the injection process and is subsequently increased again as the pressure drops. This effect becomes smaller with decreasing pulse lengths. Measurements have shown that it is even possible for a negative effect to occur in the case of pulses, which are too short. In these cases, the injected fluid substantially escapes again through the injection well, without having driven the methane in the direction of the production well. A sufficiently long pulse period must be observed.

[0028] Advantageously, the time lag between two in-

jection pulses is thus not shorter than the length of a single pulse. Measurements have shown that a negative effect may occur in the case of shorter periods, that is, the fluid is not pressed in the direction towards the production well by means of the pulse. However, longer periods are possible. A time lag between two injection pulses, which is one to ten times the pulse length, is preferred for an economically sensible operation.

[0029] The period required by the gas to cover half the distance between the injection well and the production well is particularly preferred as minimal pulse length. In this embodiment of the invention, it is thus ensured that the methane is pushed on in the direction of the production well by means of the driving fluid. In the event that measurements relating to the fluid speed in the respective coal seam are not available, a speed in the range of from 0.5 m/min to 5 m/min is assumed. The speed is thereby a function of the porosity of the respective coal seam. In the case of a coal seam comprising a high porosity, a high fluid speed can be assumed.

[0030] According to another embodiment of the invention the driving fluid is pressed out from more than one injection well in a positioned manner, wherein pulse length, pulse distance and/or start of the injection in the case of at least one injection well is/are different from pulse length, pulse distance and/or start of the injection in the case of at least one other injection well. In the event that more than one injection well is used for the positioned and pulsed injection of driving fluid flows in the direction of a production well, it is advantageous to inject both fluid flows in a time-lagged manner. Sensibly, one should make sure that the first injected fluid flow has actually arrived in the reach of the second fluid flow. A shifting of the first fluid flow in the direction of the production well thus becomes possible. In the case of an early or late injection of the second driving fluid flow, the combined fluid flow is conveyed past the production well; pulse length, pulse distance and/or time of the injections must therefore be chosen in such a manner that all of the fluid is injected in the direction of the production well.

[0031] In another embodiment of the invention, in the case of which the fluid is injected from two lines, which have the same distance from the production well, it is advantageous to start the pulses at the same time and with the same pulse length, but with different injection direction.

[0032] Advantageously, the quantities of injected fluids from at least two lines are adjusted in such a manner that the injected fluid from a first injection well is diverted in the direction of the production well by means of the quantity of the injected fluid from at least a second injection well. The quantity of injected fluid from the second injection well is thereby adjusted in such a manner that it can divert the injected fluid from the first injection well in the direction of the production well. Advantageously, the quantity of the fluid injected in the second injection well is similar to the magnitude of the quantity of the injected fluid from the first injection well. Preferably, the ratio of

the quantities of the injected fluids lies between 10:1 and 1:1. Likewise, the direction of the introduced fluids from at least two injection wells is advantageously adjusted in such a manner that the combined fluid flow from the injection wells is oriented in the direction of the production well.

[0033] Advantageously the quantities of introduced driving fluid from at least two injection wells are adjusted in such a manner that the introduced driving fluid from a first injection well is diverted in the direction of the production well by means of the quantity of the injected driving fluid from at least a second injection well.

[0034] The instant invention encompasses a number of advantages as compared to the state of the art:

- less consumption of the driving fluid,
- less driving fluid mixing into the recovered methane product gas so that less effort necessary for purification,
- more effect per volume of driving fluid injected,
- more concentrated fluid cone allows more driving force per square so that desorption gets more efficient and more methane can be recovered from a specific coal seam and
- reversion of fingering effect by directing fluid stream to adjacent volume and pushing back some of the removed product into the fingered channel. This effect can be utilized only if the injected driving fluid is adsorbed less efficiently on the coal than is methane. Notably that is true for injection of nitrogen, however not for CO₂ or water vapor.

[0035] The invention will be defined below in more detail by means of an exemplary embodiment illustrated in the figures.

Figure 1: shows an exemplary embodiment of the invention for injecting a driving fluid from two injection wells, which are located approximately at the same distance from the production well.

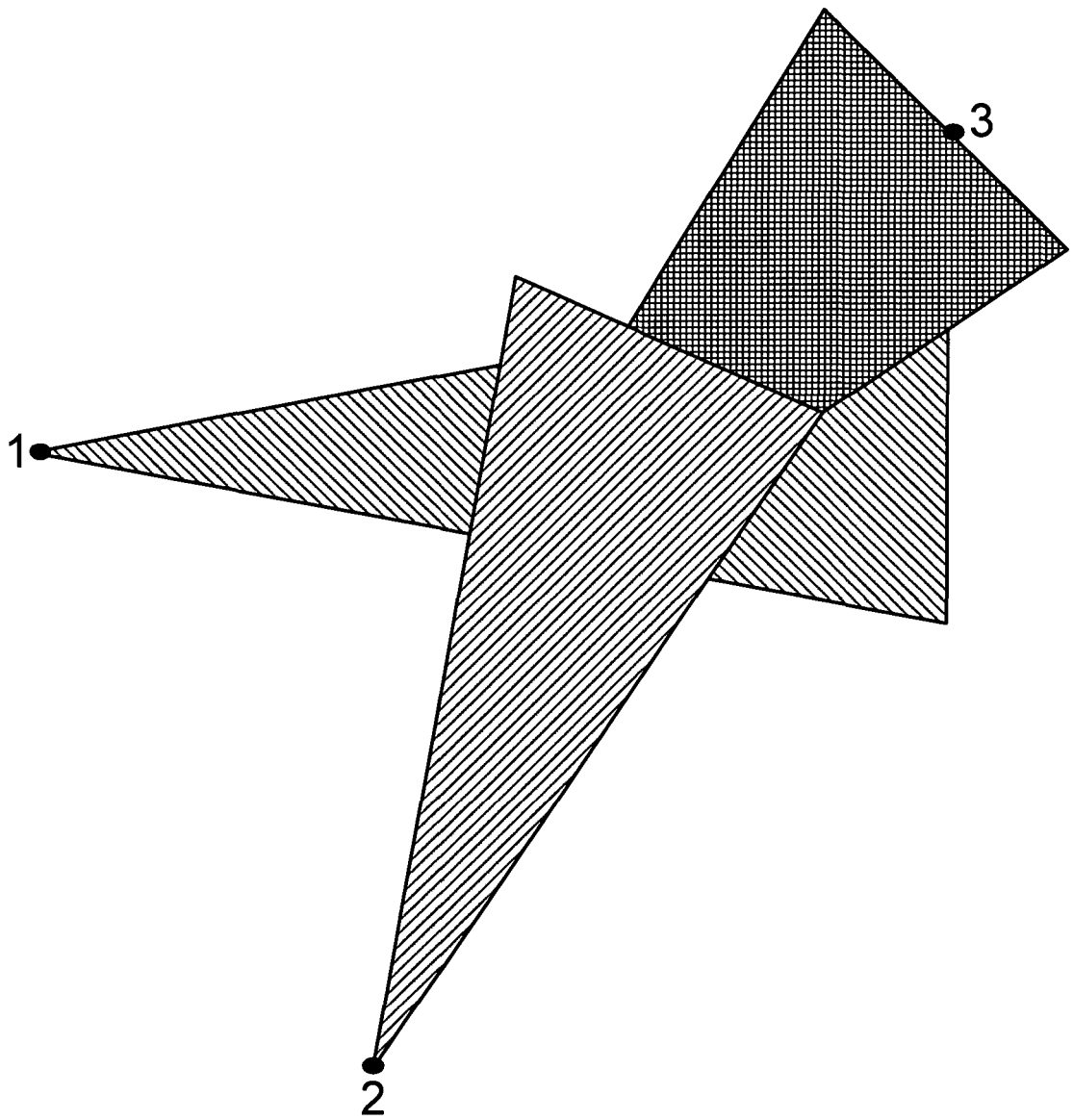
[0036] Figure 1 shows an exemplary embodiment of the method according to the invention, wherein the fluid is injected into coal seam via the two injection wells 1 and 2. Both injection wells 1 and 2 are located at approximately the same distance from the production well 3. The driving gas flow G1 is injected into the coal seam from the injection well 1 in a pulsed manner. The driving gas flow G2 is also introduced into the coal seam from the injection well 2 in a pulsed manner. Pulse durations of approx. 20 min are used thereby. The time lag between two pulses of an injection is approx. 1 hour. The injected gas quantities G1 and G2 are thereby in the same magnitude in each case. Due to the overlap of the positioned and pulsed driving gas flows G1 and G2, a resulting gas flow G3 forms, which moves in the direction of the production well 3. The methane is thus driven in the direction of the production well 3 by means of the positioned and

pulsed driving gas flows. In this embodiment of the invention, nitrogen and carbon dioxide are injected so as to alternate, so that the different characteristics of both gases can be used for the coal bed methane recovery.

Claims

1. Process for the recovery of methane contained in a coal seam, whereby a driving fluid is injected through at least one injection well into the coal seam, and whereby the desorbed products including methane are recovered by at least one production well, **characterised in that** the driving fluid is pressed out of the vertical injection well into the coal seam under pressure in a positioned and directed manner under pressure and whereby the driving fluid is pressed out of the vertical injection well into the coal seam via at least one horizontal outlet means in the wall of the vertical injection well. 10
2. Process according to claim 1, **characterised in that** carbon dioxide in the gaseous or supercritical stage and/or nitrogen in the gaseous or liquid stage, are used as driving fluid. 15
3. Process according to claim 1 or 2, **characterised in that** the driving fluid is pressed out of the injection well into the coal seam via at least one horizontal outlet means carried out as injection nozzle. 20
4. Process according to any of the claims 1 to 3, **characterised in that** pressing into the surroundings of the injection well is mainly carried out within a solid angle of 90°, preferably of 45°, particularly preferably between 10° and 30°. 25
5. Process according to any of the claims 1 to 4, **characterised in that** the direction of escape of the driving fluid, preferably the angle between main axes of the injection well and direction of escape, is changed chronologically, preferably step by step. 30
6. Process according to any of the claims 1 to 5, **characterised in that** the direction of escape of the driving fluid is oriented on the structure of the coal seam in the surroundings, that it preferably does not deviate more than 45° from the coal seam structure and that it is particularly preferably oriented parallel to the rock structure. 35
7. Process according to any of the claims 1 to 6, **characterized in that** the driving fluid is pressed in a positioned manner via two different injection wells, wherein the press-in direction of the driving fluid of the first injection well encompasses an angle to the press-in direction of the driving fluid of the second injection well. 40
8. Process according to any of the claims 7, **characterized in that** the driving fluid is pressed into the coal seam via a first injection well and via a second injection well, wherein the second injection well is not located on the connecting line between the first injection well and the production well, and the driving fluid is pressed out of the second injection well in a positioned manner such that the desorbed methane is displaced in the direction of the production well. 45
9. Process according to any of the claims 7 to 8, **characterised in that** the angle between press-in direction of the driving fluid out of the first injection well and the connecting line between first injection well and production well is changed in such a manner that the angle area between the connecting line of first injection well and production well and the connecting line of first injection well and second injection well is passed successively. 50
10. Process according to any of the claims 1 to 9, **characterised in that** the driving fluid is pressed out in succeeding pulses. 55
11. Process according to any of the claims 1 to 10, **characterised in that** the time lag between two injection pulses is not shorter than the length of a single pulse, preferably is one to ten times the pulse length.
12. Process according to any of the claims 1 to 11, **characterised in that** the driving fluid is pressed out from more than one injection well in a positioned manner, wherein pulse length, pulse distance and/or start of the injection in the case of at least one injection well is/are different from pulse length, pulse distance and/or start of the injection in the case of at least one other injection well.
13. Process according to any of the claims 1 to 12, **characterised in that** the quantities of introduced driving fluid from at least two injection wells are adjusted in such a manner that the introduced driving fluid from a first injection well is diverted in the direction of the production well by means of the quantity of the injected driving fluid from at least a second injection well.

Figure 1





EUROPEAN SEARCH REPORT

Application Number
EP 10 01 5909

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	* column 4, line 68 - column 5, line 8 * * figures 1-3 *	4,7-9	
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			E21B
Place of search		Date of completion of the search	Examiner
Munich		12 April 2011	Schouten, Adri
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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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 10 01 5909

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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