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(54) **Process for the underground gasification of coal**

(57) The invention refers to a process for underground gasification of coal whereby coal in a non-mined coal seam is converted to a product gas by in-situ gasification with an oxidant, whereby the oxidant is injected through at least one injection well and whereby the product gas is lifted through at least one production well, characterised in that the oxidant is pressed out of the essentially vertical injection well into the coal seam under pressure in a positioned and directed manner under pressure and whereby the oxidant 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.

EP 2 469 019 A1

Description

[0001] The invention is related to a process for underground gasification of coal whereby coal in non-mined coal seam is converted to a product gas by in-situ gasification with an oxidant, whereby the oxidant is injected through at least one injection well and whereby the product gas is lifted through at least one production well.

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

[0003] Underground coal gasification converts coal to gas while still in the coal seam (in-situ). Gas is produced and extracted through wells drilled into the unmined coalseam. Injection wells are used to supply the oxidants (air, oxygen) to ignite and fuel the underground combustion process. Separate production wells are used to bring the product gas to surface. The high pressure combustion is conducted at temperature of 700-900 °C, but it may reach up to 1500 °C.

[0004] The process decomposes coal and generates carbon dioxide (CO_2), hydrogen (H_2), carbon monoxide (CO) and small quantities of methane (CH_4) and hydrogen sulfide(H_2S) plus traces, as AsH_3. As the coal face burns and the immediate area is depleted, the oxidants injected are controlled by the operator.

[0005] As coal varies considerably in its resistance to flow, depending on its age, composition and geological history, the natural permeability of the coal to transport the gas is generally not adequate. For high pressure break-up of the coal, hydro-fracturing, electric-linkage, fracking with CO_2 and reverse combustion may be used in varying degrees.

[0006] A process for underground gasification of coal is disclosed in EP0155598. According to EP0155598 one or more gasification means for the gasification reaction with coal and ignition means for activating it are fed to the coal seam through a pipeline arranged in a bore extending from the earth's surface down to the coal seam. After ignition of the exothermic gasification reaction, the pipeline, with its mouth, is subsequently fed into the recess in the seam produced by burning, and in the process additional water is fed for cooling the mouth of the pipe. With the advance of a boring flame causing the burning and to reduce the gasification temperature through endothermic partial reaction, a burning channel develops, the gasification products, which form being passed to the surface through the annular space between bore and pipeline.

[0007] According to EP0155598 a pipeline is introduced in a bore. At least the lower end of the pipeline is flexible and there are means for changing the direction of the pipeline from vertical orientation to more or less horizontal orientation. This leads to a more or less horizontal fed of the gasification means e.g. the oxidant. According to this state of the art the pipeline is fed into the recess or space in the seam produced by the gasification itself.

[0008] The present invention is thus based on the object of embodying a process for underground gasification of a coal seam of the afore-mentioned type in such a manner that the needed amount of the oxidant is reduced without the requirement of flexible pipelines or other redirecting means.

[0009] The instant object is solved by a process for underground gasification of 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.

[0010] According to the present invention the oxidant is pressed out of the vertical injection well into the coal seam under pressure in a positioned and directed manner under pressure and the oxidant 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.

[0011] 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 oxidant in a directed and positioned manner into the coal seam. The directed and positioned injection of the oxidant according to the invention creates a rather finger-shaped expansion front of the oxidant. 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 oxidant into the coal seam. The simplest possibility for ensuring a positioned pressin in terms of the invention are one-sided holes in the injection well, that is, the injection well encompasses holes for the oxidant escape, which are only distributed across a part of the periphery, maximally across half of the periphery.

[0012] The oxidant is not equally distributed around the injection well. The oxidant is pressed out of the injection well in a defined directed and positioned manner. Therefore the needed amount of oxidant could be minimised. Only as much oxidant as needed for the gasification is injected. Thereby the injected amount of oxidant could be controlled precisely and adjusted to the need at the burning front of the combustion which reduces the risk of a stoichiometric combustion rather than a gasification of the coal. In general it is necessary to inject as little oxidant as possible to prevent smouldering fires. Once such fire is started it usually is very difficult to extinguish it again. Additional a reduced amount of injected oxidant leads to reduced cost and therefore to improved economy for the underground gasification of the coal seam. Furthermore the resulting product gas of the gasification is less diluted with unwanted gas resulting from a substoichiometric combustion, e.g. the oxidant itself. Thereby the suitability of the product gas for following gas to liquid product steps is improved and the number of needed purification stages reduced.

[0013] Due to the directed and positioned injection of

the oxidant according to the invention the size of the burning front of the combustion in the coal seam is reduced. This allows to control better how intensively the gasification front burns, how much gas is produced and how much unwanted carbon dioxide is formed relative to the wanted products, carbon monoxide and hydrogen. Additionally the process according to the invention allows to control how much heat is generated and thus to ensure that really only the wanted fire burns and not unwanted by-products are generated.

[0014] Within the scope of this invention, an escape of the oxidant in a positioned manner refers to the flow of the largest part of the oxidant along a preferred axis. Contrary thereto, an escape, in the case of which the oxidant 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.

[0015] Advantageously air or gaseous oxygen or a mixture of gaseous oxygen with an inert gas, preferably carbon dioxide, is used as oxidant. Depending on the concrete requirements of the coal seam, for instance geological or historical composition or natural permeability and so on, the use of the different oxidants would be more or less advantageous. Air is a cheap and easy available oxidant. The use of gaseous oxygen as oxidant would lead to a drastic reduction of the absolute amount of injected oxidant compared to air. Carbon dioxide would advantageously participate in the reaction and could have a positive effect on the formation of more wanted product gas / synthesis gas. Such an effect is known from steam methane reforming, where a carbon dioxide injection has been applied to get improved carbon utilization.

[0016] In an embodiment of the invention the oxidant is pressed out of the injection well into the coal seam via at least one horizontal outlet means carried out as injection nozzle. Injection nozzles are means, which have been well-proven in the state of the art, for establishing a fluid flow in a positioned manner.

[0017] 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 oxidant, the better the directive efficiency of the oxidant. Accordingly, much more oxidant 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 oxidant is consumed for the same effect along a certain direction of space

[0018] According to an embodiment of the invention the direction of escape of the oxidant, preferably the angle between main axis 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 oxidant 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 oxidant from one injection point into the entire coal seam. The entire coal seam can thus be gasified 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.

[0019] Advantageously the direction of escape of the oxidant 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.

[0020] Preferably the oxidant is pressed in a positioned manner via two different injection wells, wherein the press-in direction of the oxidant of the first injection well encompasses an angle to the press-in direction of the oxidant of the second injection well. In this embodiment of the invention, with a suitable angle, it is possible to press the burning front, which is driven in a direction between the production well and the second injection well by pressing in the oxidant via the first injection well, in the direction of the production well by pressing oxidant via the second injection well in a positioned manner.

[0021] Advantageously the oxidant 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 oxidant is pressed out of the second injection well in a positioned manner such that the product gas resulting from the underground gasification process is displaced in the direction of the production well.

[0022] Thereby it is preferred that the angle between press-in direction of the oxidant 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 coal in a triangle, which is formed by the three lines, e.g. the two injection wells and the production well, can be gasified in a specific manner by means of two lines for pressing in oxidant in a positioned manner and by means of one production well. By pressing in the oxidant out of the second injection well, the first oxidant flow is diverted in such a manner that the burning front is always pressed in the direction of the conveyor line from each point within the triangle. Pressing in the oxidant 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 burning front and therefore the product of the gasification away from the first injection well and quasi past the production well. Due to the superimposed press-in of oxidant out of the second injection well, this deviation, however, is again corrected in the direction of the production well.

[0023] According to another embodiment of the invention the oxidant is pressed out in succeeding pulses.

[0024] Preferably the time lag between two injection pulses is not shorter than a single pulse length. Rather it is preferably one to ten times the pulse length.

[0025] According to another embodiment of the invention the oxidant 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.

[0026] Advantageously the quantities of induced oxidant from at least two injection wells are adjusted in such a manner that the induced oxidant from a first injection well is diverted in the direction of the production well by means of the quantity of the injected oxidant from at least a second injection well.

[0027] Preferably the period required by the gas to cover half the distance between the injection well and the production well is chosen as minimal pulse length.

Claims

1. Process for underground gasification of coal whereby coal in a non-mined coal seam is converted to a product gas by in-situ gasification with an oxidant, whereby the oxidant is injected through at least one injection well and whereby the product gas is lifted through at least one production well, **characterised in that** the oxidant is pressed out of the essentially vertical injection well into the coal seam under pressure in a positioned and directed manner under pressure and whereby the oxidant 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.

2. Process according to claim 1, **characterised in that** air or gaseous oxygen or a mixture of gaseous oxygen with an inert gas, preferably carbon dioxide, is used as oxidant.

3. Process according to claim 1 or 2, **characterised in that** the oxidant is pressed out of the injection well into the coal seam via at least one horizontal outlet means designed as injection nozzle.

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°.

5. Process according to any of the claims 1 to 4, **characterised in that** the direction of escape of the oxidant, preferably the angle between main axes of the injection well and direction of escape, is changed chronologically, preferably step by step.

6. Process according to any of the claims 1 to 5, **characterised in that** the direction of escape of the oxidant 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.

7. Process according to any of the claims 1 to 6, **characterized in that** the oxidant is pressed in a positioned manner via two different injection wells, wherein the press-in direction of the oxidant of the first injection well encompasses an angle to the press-in direction of the oxidant of the second injection well.

8. Process according to claim 7, **characterized in that** oxidant 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 oxidant is pressed out of the second injection well in a positioned manner such that the product gas resulting from the underground gasification process is displaced in the direction of the production well.

9. Process according to any of the claims 7 to 8, **characterised in that** the angle between press-in direction of the oxidant 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.

10. Process according to any of the claims 1 to 9, **characterised in that** the oxidant is pressed out in succeeding pulses.

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 a single pulse length, preferably one to ten times the length of a single pulse.

12. Process according to any of the claims 1 to 11, **characterised in that** the oxidant 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 induced oxidant from at least two injection wells are adjusted in such a manner that the induced oxidant from a first injection well is diverted in the direction of the production well by means of the quantity of the injected oxidant from at least a second injection well.

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EUROPEAN SEARCH REPORT

Application Number
EP 10 01 5908

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 400 034 A (CHEW JU-NAM [US]) 23 August 1983 (1983-08-23) * column 1, line 28 - line 37 * * column 1, line 47 - line 52 * * column 3, line 64 - column 4, line 33 * * figure 2 * -----	1,2,6-9	INV. E21B43/243
X	US 3 987 852 A (TERRY RUEL C) 26 October 1976 (1976-10-26) * sentence 24, paragraph 6 - sentence 33, paragraph 8 * * figure 1 * -----	1-5, 10-13	
X	US 4 476 927 A (RIGGS JAMES B [US]) 16 October 1984 (1984-10-16) * figure 1 * -----	1,2	
X	US 2 695 163 A (PEARCE FRANK G ET AL) 23 November 1954 (1954-11-23) * figures 1,2 * -----	1,2	
			TECHNICAL FIELDS SEARCHED (IPC) E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	12 April 2011	Schouten, Adri

CATEGORY OF CITED DOCUMENTS

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12-04-2011

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- EP 0155598 A **[0006] [0007]**