



(11) **EP 3 043 021 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
13.07.2016 Bulletin 2016/28

(51) Int Cl.:
E21B 43/295 (2006.01)

(21) Application number: **14842213.2**

(86) International application number:
PCT/CN2014/074721

(22) Date of filing: **03.04.2014**

(87) International publication number:
WO 2015/032197 (12.03.2015 Gazette 2015/10)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(30) Priority: **04.09.2013 CN 201310398563**

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(54) **UNDERGROUND COAL GASIFICATION FURNACE AND UNDERGROUND COAL GASIFICATION METHOD**

(57) An underground coal gasification furnace comprises an ignition system and a gas injection system. The ignition system is provided with a first vertical drilling well (1) and a first horizontal directional drilling well (a) in communication with the first vertical drilling well. The gas injection system is provided with a second drilling well introduced into a coal seam. At least one second horizontal directional drilling wells (b, c, d, e, f) of a horizontal section in the coal seam serves as the second drilling well. Also

provided is an underground coal gasification method. The method comprises: enabling a flaming fire region of a first horizontal directional drilling well (a) to withdraw in a second horizontal directional drilling well (b, c, d, e, f) until withdraw to near a coal feeding point. The underground coal gasification furnace eliminates the defects of low cut-through speed and unstable structure in a gasification production stage in the prior art. (Fig. 3)

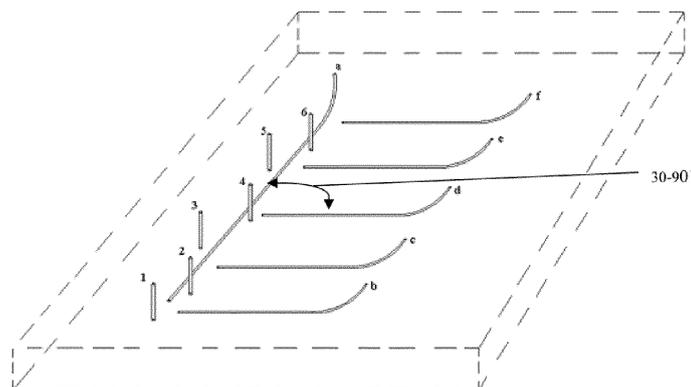


Fig. 3

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Description

Technical field

[0001] The present invention relates to an underground gasification furnace and an underground coal gasification (UCG) method.

Background

[0002] UCG relates to a process, in which the underground coal is burned under control and a combustible gas is produced by means of thermal effect and chemical reaction of coal. The underground gasification furnace is usually formed by an injection well, a gasification channel, a production well and some auxiliary monitoring wells. The gasifying agent is injected through the injection well and performs complex thermal chemical reaction with coal in the gasification channel, and the produced gas is transported to the ground through the production well.

[0003] Here the type of the underground gasification furnace in narrow sense refers to the shape of the gasification channel, and in broad sense to the shape of channel, which is formed in dependence upon the type of the bore used in underground gasification, mutual position, usage and the startup sequence during gasification.

[0004] The gasification furnace with only a pair of injection/production wells has relatively small gas production. It is difficult for smaller combustion zone to accumulate a lot of heat energy, and correspondingly the heat loss is relatively large, and it is hard to resist the influx of groundwater into the gasification furnace and to resist blockage due to coal seam roof fall. Therefore, the gasification process cannot be carried out stably. The current gasification furnace has been developed into numerous types of underground gasification furnaces by various combinations of bores with respect to types of bores (vertical wells, horizontal directional drilling wells), bore spacing, airflow direction during gasification and the direction of combustion zone expanding. Thereby gas production, the stability of gasification process and then recovery of coal resource can be increased exponentially. Furthermore, the risks of groundwater influx, roof fall and heat loss can be effectively reduced.

[0005] Therefore, the type of gasification furnace is one of the key factors that determine the success or failure of the gasification process.

[0006] Prior Art I: Angren underground gasification unit in Uzbekistan. Because Angren underground gasification station is established for a relatively long time (in 1940s), and the geological conditions are special, so the vertical drilling well is mainly used, additionally the directional drilling well is used. Vertical drilling wells are densely constructed, and the movement of combustion zones is guided by air fracturing, as shown in Figure 1.

[0007] Prior Art II: Patent 200810119354.2, it relates to a non-mine type underground gasification process,

wherein it gives an "L" shaped underground gasification furnace, which has a horizontal directional drilling well linked some vertical bores 1# to 6# as production wells system in fig 2, and the bottom of other some vertical bores (5#, 7#, 8#, 9#) has been connected by combustion in the coal seam as injection wells system in fig 2, the injection wells system is perpendicular to the production wells system in the bottom of 5# well. In expanded production phase, after the gasification furnace is formed, a first row of vertical holes is drilled at the 3# side of the line from 5# to 9# to realize the penetration of 5# to 9# with high pressure combustion, and the n_{th} row of vertical bores are sequentially drilled and the combustion zone is guided to move toward the horizontal directional drilling well, and produced gas is emitted through the production wells system to the ground.

[0008] Drawbacks of the prior art I lie in the poor directivity of the air fracturing and slow penetration speed.

[0009] Disadvantages of the prior art II lie that: ① the gasification furnace is difficult to build, the structure is not stable enough, and it is not easy to realize the connection of one horizontal directional drilling well with a plurality of vertical bores, even if it is achieved, there is a risk of drilling blockage if they are not used as soon as possible later; ② in the penetration production cycle, the operation is difficult. Multiple rows of vertical wells require to be penetrated by means of high pressure combustion, and the operation is difficult in the constant switching cycle between high pressure combustion penetration and gasification production.

SUMMARY OF THE INVENTION

[0010] Aiming to the technical problems in the prior art, an object of the invention is to provide an underground coal gasification furnace, and underground coal gasification process, so as to at least eliminate the defects in the gasification stage of production in the prior art, e.g., slow penetration speed and unstable structure.

[0011] On the one hand, the present invention provides an underground coal gasification furnace, comprising an ignition system and an injection system. The ignition system has a first vertical well drilled into coal seam, and a first horizontal directional drilling well with horizontal section in the coal seam and in communication with the first vertical drilling well. The injection system has a second drilling well into the coal seam and in communication with the first horizontal directional drilling well, wherein the second drilling well is at least one second horizontal directional drilling well with a horizontal section in the coal seam.

[0012] Preferably, the first horizontal directional drilling well is communicated with the second horizontal directional drilling well in a manner of reverse combustion.

[0013] Preferably, the second drilling well refers to at least two second horizontal directional drilling wells parallel to each other, which are arranged on one side or on both sides of the first horizontal directional drilling well in

the direction of intersecting the first horizontal directional drilling well.

[0014] Preferably, the second horizontal directional drilling well forms an angle of 30° -90° with the first horizontal directional drilling well.

[0015] Preferably, at least one second vertical drilling well is disposed along the first horizontal directional drilling well, wherein all of the second vertical drilling wells are in communication with each other by means of reverse combustion in the first horizontal directional drilling well to form the production wells system.

[0016] Preferably, the end of the horizontal section of the first horizontal directional drilling well is communicated with the first vertical drilling well by means of combustion or directional blasting or cold-state fracturing.

[0017] Preferably, the second drilling well refers to at least two second horizontal directional drilling wells, which are arranged on the same side of the first horizontal directional drilling well, one of which is directed to and is communicated with the first horizontal directional drilling well by means of fracturing; at least one third vertical drilling well is arranged along said one of the second horizontal directional drilling wells, wherein said one of the second horizontal directional drilling wells is communicated with the third vertical drilling well by means of reverse combustion and form together the injection wells system.

[0018] Preferably, the nude section of each of all drilling wells (including horizontal directional drilling well and vertical drilling well) located in the coal seam is supported and protected by a support and protect arrangement.

[0019] Preferably, the supporting and protection arrangement is a sieve pipe or seamless pipe.

[0020] Preferably, a towable gasifying agent-introduction pipe is arranged at least in one of said second horizontal directional drilling wells, the gas injection end of which moves when the gasifying agent-introduction pipe is towed.

[0021] On the other hand, the present invention provides an underground coal gasification process, including: the step of constructing an underground coal gasification furnace according to the present invention; and the step of performing gasification in the constructed gasification furnace, comprising: guiding the combustion zone of the first horizontal directional drilling well to retreat in the second horizontal directional drilling well until back to the vicinity the coal feeding point of the second horizontal directional drilling well.

[0022] Preferably, the step of constructing an underground gasification furnace includes the following sub-steps 1-2, which are performed sequentially: the sub-step 1: the following drilling wells are drilled one after another: the first vertical drilling well entering into the coal seam, the first horizontal directional drilling well with the horizontal section in the coal seam, at least two second vertical drilling wells arranged along the first horizontal directional drilling well, and at least two second horizontal directional drilling wells arranged on one side or on both

sides of the first horizontal directional drilling well and having the horizontal section in the coal seam, all these drilled drilling wells are not communicated with each other; and the sub-step 2: firstly realizing the communication between the first horizontal directional drilling well and the first vertical drilling well, and then igniting the coal seams at the bottom of the first vertical drilling well, injecting gasifying agent into the first horizontal directional drilling well, guiding the movement of the combustion zone in the first horizontal directional drilling well, until realizing the communication with the rest of drilling wells in the sub-step 1.

[0023] Preferably, the pressure air is introduced into the second horizontal directional drilling well when the combustion zone moved in the first horizontal directional drilling well, wherein the pressure of the pressure air is greater than that in the first horizontal directional drilling well.

[0024] Preferably, the guided movement of the combustion zone in the sub-step 2 is realized by towing the coiled tubing also is the gasifying agent-introduction pipe in the first horizontal directional drilling well to make its injection end move.

[0025] Preferably, the first horizontal directional drilling well is drilled toward the first vertical drilling well against the developing direction of cracks in coal seam.

[0026] Preferably, the step of constructing an underground coal gasification furnace includes the following sub-steps 1-3, which are performed sequentially: the sub-step 1: the first vertical drilling well and at least two second vertical drilling wells are drilled successively in the developing direction of cracks in coal seam, which enter into the coal seam and are separated from each other, and then the first horizontal directional drilling well is drilled against the developing direction of cracks in coal seam towards the direction of the first vertical drilling well, which first horizontal directional drilling well communicates the first vertical drilling well and some second vertical drilling well in the coal seam; the sub-step 2: at least two second horizontal directional drilling wells are drilled on one side of the first horizontal directional drilling well, wherein the ends of said at least two second horizontal directional drilling wells are directed to the first horizontal directional drilling well, wherein the end of some second horizontal directional drilling wells is communicated with the first horizontal directional drilling well, and the end of the other second horizontal directional drilling wells keeps a certain distance from the first horizontal directional drilling well; the sub-step 3: the coiled tubing is inserted into the first horizontal directional drilling well, and the gasifying agent is injected into the first horizontal directional drilling well at the gas injection end of the coiled tubing, the coiled tubing is towed to guide the movement of the combustion zone to perform to the first horizontal directional drilling well, until the other second horizontal directional drilling wells are communicated with the other second vertical drilling wells.

[0027] Preferably, the sub-step 2 further comprises: a

fourth vertical drilling well is drilled into the coal seam on one side of the first horizontal directional drilling well, and is respectively communicated with the second horizontal directional drilling well in one-to-one manner. When the combustion zone in the second horizontal directional drilling well passes the bottom of the fourth vertical drilling well, the fourth vertical drilling well is used as gas production well instead of the first vertical drilling well, the second vertical drilling well and the first horizontal directional drilling well during the gasification furnace is constructed.

[0028] Preferably, when the gasifying agent introduction pipe in some second horizontal directional drilling well is towed to move the combustion zone, the other second horizontal directional drilling well is used as production well, wherein the gasifying agent introduction pipe in these second horizontal directional drilling well is drawn out, the first horizontal directional drilling well, the first vertical drilling well and the arranged second vertical drilling well are closed.

[0029] Preferably, the step of constructing an underground coal gasification furnace includes: (I) to construct an ignition system and an production well system for gasification furnace by means of the following way: the following drilling wells entering into the coal seam are drilled one after another: the first vertical drilling well; the first horizontal directional drilling well and one second horizontal directional drilling well which are perpendicular to each other and have the horizontal section in the coal seam; a second vertical drilling well and a third vertical drilling well, which are arranged crosswise respectively along these two horizontal directional drilling wells; then these two horizontal directional drilling wells are communicated with the first vertical drilling well through fracturing, and then the first horizontal directional drilling well is subjected to reverse combustion until the second vertical drilling well along the line is linked to form the ignition system, as well as the second horizontal directional drilling well is subjected to reverse combustion until the third vertical drilling well along the line is linked to form the production wells system; and (II) another second horizontal directional drilling well parallel to said one second horizontal directional drilling well is drilled while the ignition system and the production wells system for gasification furnace are constructed, wherein the horizontal section of said another second horizontal directional drilling well is located in the coal seam, and the end of the horizontal section is directed to the first horizontal directional drilling well and is communicated with the same by fracturing.

[0030] Preferably, the reverse combustion is realized in the following manner: igniting the coal seam in the first vertical drilling well, towing the gas injection end of the coiled tubing in the first horizontal directional drilling well and said one second directional drilling well to guide the combustion zone to move along these two horizontal directional drilling wells to realize reverse combustion.

[0031] The underground coal gasification furnace and

the underground coal gasification according to the present invention have the beneficial effects: eliminating the defects in gasification production stage in the prior art, e.g., slow penetration speed, and unstable structure.

Brief Description OF Drawings

[0032]

Figure 1 is a schematic diagram of Angren underground gasification unit in prior art I;

Figure 2 is a schematic structural diagram of the L-shaped underground gasification furnace in prior art II;

Figure 3 is a schematic diagram of the frame structure of the underground coal gasification furnace before its formation according to the present invention;

Figure 4 is a schematic diagram of the frame structure of the underground coal gasification furnace according to Example 1 of the present invention;

Figure 5 is a schematic diagram of the frame structure of the underground coal gasification furnace according to Example 2 of the present invention;

Figure 6 is a schematic diagram of the frame structure of the underground coal gasification furnace according to Example 3 of the present invention;

Figure 7 is a schematic diagram of the frame structure of the underground coal gasification furnace according to Example 3 of the present invention.

Detailed Embodiments

[0033] Hereafter the embodiments of the underground coal gasification furnace and the underground coal gasification process according to the present invention are described with reference to Figs. 3-7.

[0034] Fig. 3 shows an example of the frame structure of the underground coal gasification furnace, wherein the respective drilling wells are separated from each other (i.e., non-communication, or spaced at a distance, or separated from each other), when the respective drilling wells are communicated, the frame structure of the underground coal gasification furnace is constructed as underground coal gasification furnace. Thus, the underground coal gasification furnace according to the present invention is described with reference to Fig. 3, which includes: an ignition system and a gas injection system. The ignition system has a first vertical drilling well 1 entering into coal seam, and a first horizontal directional drilling well a with a horizontal section in the coal seam and in communication with the first vertical drilling well 1; the gas injection system has a second drilling entering

into the coal seam and in communication with the first horizontal directional drilling well a, wherein the second drilling is at least one second horizontal directional drilling well b, c, d, e, f with a horizontal section in the coal seam.

[0035] Preferably, it is possible to at least arrange a towable gasifying agent-introduction pipe in one second horizontal directional drilling wells b, c, d, e, f, and the gas injection end of this pipe moves when the gasifying agent-introduction pipe is towed.

[0036] One example for the underground coal gasification furnace and the underground coal gasification process according to the present invention is described in the following (1) to (3) with reference to Fig. 3 in detail.

(1) Construction phase of the frame structure of the underground coal gasification furnace: Firstly, a first vertical drilling well 1 is drilled at some point in the coal seam to the middle lower part of the coal seam to be gasified,; the first horizontal directional drilling well a is drilled against the developing direction of cracks in coal seam, which is determined according to geological data, the horizontal section of the first horizontal directional drilling well a is located in the middle lower part of the coal seam, and its end is directed to and spaced from the first vertical drilling well 1 at a distance of 5-20m, the first vertical drilling well 1 and the first horizontal directional drilling well a form the ignition system; then the second vertical drilling wells 2-6 are drilled at a distance of 5-20m from both sides of the first horizontal directional drilling well a, which are spaced from each other at a distance of 30-50m to the middle lower part of the coal seam to form the production wells system. At last, a plurality of second horizontal directional drilling wells b-f parallel to each other are drilled in the direction forming an angle of 30° - 90° with the first horizontal directional drilling well a (here the angle is formed by the projections of the first horizontal directional drilling well and the second horizontal directional drilling wells on the ground) to form a gas injection wells system, the ends of these second horizontal directional drilling wells b-f are separated from the first horizontal directional drilling well a (namely without communication), and are spaced from the same at a distance of 5-20m. This distance is rough estimated according to the semi diameter of the horizontal drilling well after reverse combustion adding the length of the developed cracks in the heated coal seam. It is best to install a support and protect arrangement in the nude section in the coal seam for supporting and protecting the bore holes when one well is drilled, said support and protect arrangement may be sieve pipes or seamless pipes made of PVC, combustible materials, or glass fiber reinforced plastic, preferably seamless glass fiber reinforced plastic pipe.

(2) Gasification phase: it aims to realize formation of

the underground coal gasification furnace and large-scale production. Firstly, the first horizontal directional drilling well a is communicated with the first vertical drilling well 1 by means of directional blasting, cold-state fracturing or combustion penetration; and then the coal seam is ignited at the bottom of the first vertical drilling well 1, gasifying agent is injected into the first horizontal directional drilling well a, the combustion zone is guided to move towards the direction of the second vertical drilling well 6 (namely a reverse combustion), the coal seam surrounding the first horizontal directional drilling well a is burned to enlarge the diameter of the first horizontal directional drilling well a, during this process, it is best to increase pressure (by means of coiled tubing) in the second vertical drilling wells 2-6 and in the horizontal directional drilling wells b-f, which is a little greater than the pressure in the first horizontal directional drilling well a. It is to determine according to the pressure variation in the second vertical drilling wells 2-6 and in the horizontal directional drilling wells b-f, whether the communication with the first horizontal directional drilling well a is realized. It is also possible to not increase pressure in the second vertical drilling wells 2-6 and in the horizontal directional drilling wells b-f; the coal seam of the horizontal section of the first horizontal directional drilling well a is burned until all vertical drilling wells and direction drilling wells are communicated with the combustion zone, at this time the construction of the underground coal gasification furnace is finished. That is, the first horizontal directional drilling well a is communicated with all second vertical drilling wells 2-6 and with the second horizontal directional drilling wells b-f by means of reverse combustion in the underground coal gasification furnace.

(3) At last, some of drilling wells are selected as the production wells system and some of them are selected as the gas injection wells system. The gas injection end of the coiled tubing is inserted into respective drilling wells of the gas injection wells system, and the gas injection speed is controlled by the coiled tubing to gasify the coal seam before the gas injection end. When the contents of the effective components in the produced coal gas are reduced obviously, the gas injection end of the coiled tubing is drawn back by 20-30m by means of the ground towing device, and gasification agent is further injected to guide the combustion zone to move towards the coiled tubing. When the contents of the effective components in the coal gas are again reduced obviously, then the coiled tubing is drawn back once more until the combustion zone extends in the vicinity of the coal feeding point of drilling wells.

[0037] The gas used in the fracturing, combustion penetration and gasification should be same according to

the use of coal gas so as to avoid negative influence on the following operation phase. For example, if coal gas is used for power generation by burning, then it is better that the gas used in respective phases is oxygen-enriched air; if coal gas is used for forming methane, then it is better that the gas used in respective phases is pure oxygen-water vapour, pure oxygen or pure oxygen/carbon dioxide.

[0038] The underground coal gasification furnace and the underground coal gasification process according to the present invention are further explained according to examples 1 to 4 in the following.

[Example 1]

[0039] The underground coal gasification furnace and the underground coal gasification process according to the present invention are explained by taking bituminous coal seam having buried depth of 500m and horizontal thickness of 10m at some place as an example.

[0040] Firstly, referring to Fig. 4, a first vertical drilling well 1 is drilled to the middle lower part of the coal seam in the selected area for constructing the underground gasification furnace; the first horizontal directional drilling well a is drilled against the developing direction of cracks in coal seam towards the first vertical drilling well 1; the first horizontal directional drilling well a has a 250m horizontal bore hole at the middle lower part of the coal seam. The second vertical drilling wells 2-7 are drilled into the middle lower part of the coal seam at a distance of about 5m from both sides of the first horizontal directional drilling well a, which are spaced from each other at a distance of 25m. The second vertical drilling wells 2-7 are alternatively disposed on both sides of the first horizontal directional drilling well a.

[0041] Then a plurality of second horizontal directional drilling wells b-k parallel to each other are drilled at a distance towards the directional drilling a on both sides of the first horizontal directional drilling well a, the horizontal drilling wells in the middle lower part of the coal seam all have the length greater than 200m. The adjacent two second horizontal directional drilling wells have a distance of 25m there-between. The drilling well is stopped at a distance of about 5m from the first horizontal directional drilling well a, that is, it is separated from the first horizontal directional drilling well a (namely without communication). For no matter vertical drilling well or horizontal drilling well, it is to install a seamless glass fiber reinforced plastic pipe in the nude bore hole in the coal seam for supporting and protecting when one well is finished. Here the frame structure of the gasification furnace is shown as in Fig. 4.

[0042] Then high pressure air of about 4.0Mpa is introduced into the first horizontal directional drilling well a through the coiled tubing to realize communication with the first vertical drilling well 1 by means of fracturing penetration. After communication, the coal seam is ignited at the bottom of the first vertical drilling well 1, air is in-

jected from the first horizontal directional drilling well a, the air injection amount of the coiled tubing is controlled to guide the combustion zone to move from the bottom of first vertical drilling well 1 to the direction of the second vertical drilling well 7 to form the ignition system. During this period, high pressure air is introduced into the second vertical drilling wells 2-7 and the gas injection end of the coiled tubing is inserted into the second horizontal directional drilling wells b-g at a distance of about 20m from the first horizontal directional drilling well a. High pressure air is introduced into the second horizontal directional drilling wells b-g through the coiled tubing, wherein the pressure therein is a little greater than the pressure in the first horizontal directional drilling well a by 0.5Mpa. Whether communication is realized is adjusted according to the pressure variation in respective drilling wells, until the second vertical drilling wells 2-7 are communicated with the first horizontal directional drilling well a and the second horizontal directional drilling wells b-g are communicated with the first horizontal directional drilling well a.

[0043] At last, the production wells system is formed. The first vertical drilling well 1 and the second vertical drilling wells 2-7 as well as the first horizontal directional drilling well a are using as production wells system. Air is continuously injected into the second horizontal directional drilling wells b and g through the coiled tubing to perform reverse combustion gasification. When the contents of the effective components in the produced coal gas are reduced obviously after a stable time period, the gas injection end is drawn back by 20m by means of the ground towing device for the coiled tubing, and air is continuously injected to guide the combustion zone to move towards the gas injection end. When the contents of the effective components in the coal gas are increased, keeps stable for a period and then reduced obviously again, then the coiled tubing is drawn back once more until the combustion zone extends in the vicinity of the coal feeding point of the second horizontal directional drilling wells b and g, so as to gasify the coal under control of the second horizontal directional drilling wells b and g.

[0044] The gas injection end of the coiled tubing is inserted into the second horizontal directional drilling wells c and h. The same operations are performed as for the second horizontal directional drilling wells b and g to gasify the coal under control of the second horizontal directional drilling wells c and h. Similarly, the coal is gasified under control of the second horizontal directional drilling wells d and i, e and h, f and k successively. It is also possible to begin the gasification of the second horizontal directional drilling wells c and h when the gasification of the second horizontal directional drilling wells b and g is half finished. The piece of coal seam is totally gasified in this way to realize the large-scale production of underground gasification technology.

[0045] In Fig. 3, the second horizontal directional drilling wells are arranged on one side of the first horizontal directional drilling well a in the direction intersecting the

first horizontal directional drilling well a. Compared with Fig. 3, Fig. 4 shows that the second horizontal directional drilling wells are arranged on both sides of the first horizontal directional drilling well a in the direction intersecting the first horizontal directional drilling well a.

[Example 2]

[0046] The underground coal gasification furnace and the underground coal gasification process according to the present invention are explained by taking lignite coal seam having buried depth of 300m and horizontal thickness of 8m at some place as an example.

[0047] Firstly, the developing direction of cracks in coal seam is determined according to geological data in the selected coal seam area for underground gasification, as shown by arrow in Fig. 5. At one selected point, a first vertical drilling well 1 is drilled to the middle lower part of the coal seam; a second vertical drilling well is drilled into the middle lower part of the coal seam in the developing direction of cracks in coal seam at interval of about 35m and is numbered as 2, 3, 4, 5, 6; the first horizontal directional drilling well a is drilled against the developing direction of cracks in coal seam towards the first vertical drilling well 1; the horizontal section of the drilling well has a length of about 250m at the middle lower part of the coal seam; this horizontal directional drilling well in the middle lower part of the coal seam is communicated with the first vertical drilling well 1 and with part of the second vertical drilling wells (e.g., the second vertical drilling wells 4, 6) as far as possible, and the rest of the second vertical drilling wells (e.g., the second vertical drilling wells 2, 3, 5) are spaced from the first horizontal directional drilling well a at a distance of 5-20m.

[0048] Then vertical drilling wells are drilled into the middle lower part of the coal seam at a distance of about 100m from one side of the first horizontal directional drilling well a, and are numbered as 1", 2", 3", 4", 5" and are spaced from each other at a distance of about 35m. On the same side of the first horizontal directional drilling well a, a plurality of second horizontal directional drilling wells b, c, d, e, f parallel to each other are drilled towards the first horizontal directional drilling well a and the drilling wells in the middle lower part of the coal seam have the length greater than about 200m, wherein the second horizontal directional drilling wells b, d, f are communicated with the first horizontal directional drilling well a as far as possible, and the ends of the second horizontal directional drilling wells c and e are spaced from the first horizontal directional drilling well a at a distance of about 5-20m. The second horizontal directional drilling wells b, c, d, e, f may be communicated with the fourth vertical drilling wells 1"-5" or not. Here the constructed frame structure of the gasification furnace is shown as in Fig. 5.

[0049] Hereafter, the gas injection ends of several sets of the coiled tubing are respectively inserted into the first horizontal directional drilling well a and the second horizontal directional drilling wells b, c, d, e, f, wherein the

gas injection end in the first horizontal directional drilling well a is at a distance of about 20m from the bottom of the first vertical drilling well 1. The gas injection ends in the second horizontal directional drilling wells b, c, d, e, f are at a distance of about 20m from the first horizontal directional drilling well a. The O_2/CO_2 is used as gasifying agent is introduced into the first horizontal directional drilling well a at the gas injection end of the coiled tubing, the coal seam is ignited at the bottom of the first vertical drilling well 1, and combustion is extended with the help of O_2/CO_2 . When the contents of the effective components in the produced coal gas are reduced obviously, the gas injection end of the coiled tubing is drawn back by 20m by means of the ground towing device, and O_2/CO_2 is continuously injected to guide the combustion zone to move towards the second vertical drilling well 6, until the combustion zone extends to the bottom of the second vertical drilling well 6. The diameter of the channel in the first horizontal directional drilling well a can be enlarged from 100mm to about 1.5m due to combustion. In this situation, vertical drilling wells and directional drilling wells (the second horizontal directional drilling wells c, e and the second vertical drilling wells 2, 3, 5), which are not communicated with the first horizontal directional drilling well a originally, can be communicated with the first horizontal directional drilling well a due to thermal effect. At this time, the gasification furnace has been constructed.

[0050] At last, the first vertical drilling well 1, the second vertical drilling wells 2, 3, 4, 5, 6 and the first horizontal directional drilling well a are used as production wells and form thereby the production wells system. The second horizontal directional drilling wells b, c, d, e, f are used as gas injection wells and form thereby the injection wells system. At the same time, O_2/CO_2 is injected into the combustion zone by activating the coiled tubing, and gas injection amount is controlled to guide the combustion zone to extend towards the gas injection end. When the contents of the effective components in the produced coal gas are reduced obviously, the gas injection end of the coiled tubing is drawn back by 20m by means of the ground towing device, and O_2/CO_2 is continuously injected. The above operations are repeated, so as to guide the combustion zone to move in the line of the vertical drilling wells 1-6 towards the line of the fourth vertical drilling wells 1"-6". When the combustion zone moves under the vertical drilling wells 1"-6", it is possible to use the fourth vertical drilling wells 1"-6" as gas outlet wells to replace the original exhaust system for gas outlet. A plurality of directional drilling wells perform gasification at the same time so as to realize the large-scale production of underground gasification technology.

[Example 3]

[0051] The underground coal gasification furnace and the underground coal gasification process according to the present invention are explained by taking sub-bitu-

minous coal seam having buried depth of 600m and horizontal thickness of 12m at some place as an example.

[0052] Firstly, referring to Fig. 6, a first vertical drilling well 1 is drilled to the middle lower part of the coal seam in the selected area for constructing the underground gasification furnace; the first horizontal directional drilling well a is drilled against the developing direction of cracks in coal seam towards the first vertical drilling well 1; the first horizontal directional drilling well a has a horizontal bore hole with a length of 250m at the middle lower part of the coal seam. The second vertical drilling wells 2-3 are drilled into the middle lower part of the coal seam at a distance of 5-15m from one side of the first horizontal directional drilling well a at intervals of about 100m. The second vertical drilling wells 2-3 are disposed on the same side of the first horizontal directional drilling well a.

[0053] Then a plurality of second horizontal directional drilling wells b-k parallel to each other are drilled at a distance towards the first horizontal directional drilling well a on both sides of the first horizontal directional drilling well a, the horizontal drilling wells in the middle lower part of the coal seam all have the length greater than 200m. The adjacent two second horizontal directional drilling wells have a distance of 30m there-between. The drilling well is stopped at a distance of about 5-20m from the first horizontal directional drilling well a, that is, it is separated from the first horizontal directional drilling well a (namely without communication). For no matter vertical drilling well or horizontal drilling well, it is to install a seamless glass fiber reinforced plastic pipe in the nude bore hole in the coal seam for supporting and protecting when one well is finished. Here the frame structure of the gasification furnace is shown as in Fig. 6.

[0054] Then the coiled tubing together with its gas injection end are inserted into the first horizontal directional drilling well a, and the gas injection end is at a distance of about 15m from the bottom of the first horizontal directional drilling well a in the coal seam. Oxygen-enriched air having pressure of about 4.0Mpa is injected into the first horizontal directional drilling well a through the gas injection end of the coiled tubing to realize communication with the first vertical drilling well 1 by means of fracturing penetration. After communication, the coal seam is ignited at the bottom of the first vertical drilling well 1, oxygen-enriched air is injected to the first horizontal directional drilling well a through the coiled tubing, the gas injection amount is controlled to guide the combustion zone to move towards the gas injection end. When the contents of the effective components in the produced coal gas are reduced obviously, the gas injection end of the coiled tubing is drawn back by 20m by means of the ground towing device, so as to guide the combustion zone to further move towards the gas injection end, until the combustion zone extends to the bottom of the second vertical drilling well 3. Thereby the ignition system for the gasification furnace is formed. Just in case of unsuccessful combustion of the ignition system, or some drilling wells of the production wells system fail to function in the

future, the second vertical drilling wells 2 and 3 are drilled.

[0055] At last, the ignition system is closed, namely stopping the gas injection or production of the first vertical drilling well 1 and the first horizontal directional drilling well a, and closing other vertical drilling wells, and withdrawing the coiled tubing from the second horizontal directional drilling wells c, e, h, j and taking these drilling wells as gas production wells. Oxygen-enriched air is continuously injected into the second horizontal directional drilling wells b, d, f, g, i, k through the coiled tubing to perform reverse combustion gasification. When the contents of the effective components in the produced coal gas are reduced obviously, the gas injection end is drawn back by 20m by means of the ground towing device for the coiled tubing, and oxygen-enriched air is continuously injected to guide the combustion zone to move towards the gas injection end. When the contents of the effective components in the coal gas are increased, keeps stable and then reduced obviously again, then the gas injection end is drawn back once more until the combustion zone extends in the vicinity of the coal feeding point of the directional drilling wells, so as to realize the large-scale production of underground gasification technology.

[Example 4]

[0056] In this example, it is to construct the ignition system and the production wells system for the gasification furnace by vertical drilling wells and directional drilling wells. The details are shown in Fig. 7 as follows:

Firstly, a first vertical drilling well 1 is drilled to the middle lower part of the coal seam at some point in the coal seam to be gasified;

[0057] Then, the first horizontal directional drilling well a and the second horizontal directional drilling well b perpendicular to each other are drilled at a distance towards the first vertical drilling well 1, the horizontal drilling wells in the middle lower part of the coal seam all have the length greater than 200m. The ends of the horizontal sections of the two drilling wells are both directed to the first vertical drilling well 1, and are at a distance of about 7m from the bottom of the first vertical drilling well 1.

[0058] And then, the second vertical drills are drilled at intervals of about 70m within the distance of 10m from the first horizontal directional drilling well a on the left and right to the middle lower part of the coal seam and are arranged crosswise on both sides of the first horizontal directional drilling well a and are number as 2, 3, 4; the third vertical drills are drilled at intervals of about 30m within the distance of 10m from the second horizontal directional drilling well b on the left and right to the middle lower part of the coal seam and are arranged crosswise on both sides of the second horizontal directional drilling well b and are number as 2', 3', 4', 5', 6', 7', 8', 9', 10'.

[0059] At last, the coiled tubing together with its gas

injection end are inserted into the first horizontal directional drilling well a, and the second horizontal directional drilling well b; the gas injection ends are at a distance of about 15m from the bottom of the first vertical drilling well 1, and then the coal seam is ignited in the first vertical drilling well 1. The gas injection amount of the coiled tubing is controlled to guide the combustion zone to move along the first horizontal directional drilling well a and the second horizontal directional drilling well b to perform reverse combustion. The first vertical drilling well 1 is used as coal gas production well. When the contents of the effective components in the coal gas are reduced obviously, the gas injection end of the coiled tubing is drawn back by 15m by means of the ground towing device, and air is further injected to guide the movement of the combustion zone. After repetitively withdrawing the gas injection end of the coiled tubing, an equivalent diameter of the first horizontal directional drilling well a, and the second horizontal directional drilling well b can reach 1.5m; furthermore, thermal effect promotes the development of the cracks in the coal seam so as to penetrate the third vertical drilling wells 2'-10' and the second vertical drilling wells 2-4 in the line of the first horizontal directional drilling well a and the second horizontal directional drilling well b. Thereby the ignition system (the first horizontal directional drilling well a and the second vertical drilling wells along the line thereof) as well as the production wells system (the second horizontal directional drilling well b and the third vertical drilling wells along the line thereof) for the present gasification furnace are formed.

[0060] While the ignition system and the production wells system for the gasification furnace are constructed, it is possible to drill other second horizontal directional drilling wells c, d, e, f, which are parallel to the above said second horizontal directional drilling well b, and the ends of which are directed to the first horizontal directional drilling well a, and the horizontal drilling wells in the middle lower part of the coal seam all have the length greater than 200m. After the wells have been drilled, the coiled tubing together with its gas injection end are inserted, and the communication with the ignition system is realized by means of high pressure fracturing. Just as the above said, the coal gas is produced through production wells system. The combustion zone is guided by withdrawing the coiled tubing to extend along the directional drilling wells. The gas injection end is drawn back according to obvious variation of effective components in the coal gas. Gasification is performed in a plurality of horizontal directional drilling wells at the same time. It is necessary to install a seamless glass fiber reinforced plastic pipe in the nude bore hole in the coal seam in time for supporting and protecting when one well is finished.

[0061] According to the above description with reference to Figs. 3-7, the underground coal gasification process according to the present invention includes: the step of constructing an underground coal gasification furnace according to the present invention; and the step of per-

forming gasification in the underground coal gasification furnace, comprising: guiding the combustion zone of the first horizontal directional drilling well a to retreat in the second horizontal directional drilling well until back to the coal feeding point of the second horizontal directional drilling well.

[0062] It is easy to understand, the gasifying agent injection pipe can be towed in at least one second horizontal directional drilling wells b-g to realize guiding the retreat of the combustion zone of the first horizontal directional drilling well a in the second horizontal directional drilling well.

[0063] In order to further understand the underground coal gasification process according to the present invention, the underground coal gasification process according to the present invention is further explained with reference to Figs. 3, 4, 6, with reference to Fig. 5, and with reference to Fig. 7 as follows:

It can be seen according to Figs. 3, 4, 6, the step of constructing an underground coal gasification furnace includes the following sub-steps 1-2, which are performed sequentially. Here the sub-step 1 is: the following drilling wells are drilled one after another: a first vertical drilling well 1 entering into the coal seam, a first horizontal directional drilling well a with a horizontal section in the coal seam, at least two second vertical drilling wells 2, 3, 4, 5, 6 arranged along the first horizontal directional drilling well a, and at least two second horizontal directional drilling wells b, c, d, e, f arranged on one side or on both sides of the first horizontal directional drilling well a and having a horizontal section in the coal seam, wherein all these drilled drilling wells are separated from each other (namely without communication). The sub-step 2 is: firstly communicating the first horizontal directional drilling well a with the first vertical drilling well 1, and then igniting the coal seam at the bottom of the first vertical drilling well 1, injecting gasifying agent into the first horizontal directional drilling well a, guiding the movement of the combustion zone to perform reverse combustion to the first horizontal directional drilling well a, until realizing the communication with the rest of drilling wells in the sub-step 1.

[0064] It can be seen according to Fig. 5, the step of constructing an underground coal gasification furnace includes the following sub-steps 1-3, which are performed sequentially. The sub-step 1 is: the first vertical drilling well 1 and at least two second vertical drilling wells 2, 3, 4, 5, 6 are drilled successively in the developing direction of cracks in coal seam, which enter into the coal seam and are separated from each other, and then the first horizontal directional drilling well a is drilled against the developing direction of cracks in coal seam towards the direction of the first vertical drilling well 1, the first horizontal directional drilling well communicates the first vertical drilling well 1 and some second vertical drilling wells

2, 3, 4, 5, 6 in the coal seam. The sub-step 2 is: at least two second horizontal directional drilling wells b, c, d, e, f are drilled on one side of the first horizontal directional drilling well a, wherein the ends of said at least two second horizontal directional drilling wells are directed to the first horizontal directional drilling well a, wherein the end of some second horizontal directional drilling wells b, d, f is communicated with the first horizontal directional drilling well a, and the end of the other second horizontal directional drilling wells c, e keeps a certain distance from the first horizontal directional drilling well a (namely being separated or without communication). The sub-step 3 is: the coiled tubing is inserted into the first horizontal directional drilling well a, and the gasifying agent is injected into the first horizontal directional drilling well a at the gas injection end of the coiled tubing, the coiled tubing is towed to guide the movement of the combustion zone to perform reverse combustion to the first horizontal directional drilling well a, until the other second horizontal directional drilling wells c, e are communicated with the other second vertical drilling wells 2, 3, 4, 5, 6.

[0065] It can be seen according to Fig. 7, the step of constructing an underground gasification furnace includes (I) and (II). Particularly, (I) to construct an ignition system and gas production wells system for gasification furnace by means of the following way: the following drilling wells entering into the coal seam are drilled one after another: the first vertical drilling well 1; the first horizontal directional drilling well a and one second horizontal directional drilling well b which are perpendicular to each other and have the horizontal section in the coal seam; a second vertical drilling wells 2, 3, 4 and a third vertical drilling wells 2'-10', which are respectively arranged crosswise along these two horizontal directional drilling wells; then these two horizontal directional drilling wells are communicated with the first vertical drilling well 1 through fracturing, and then the first horizontal directional drilling well a is subjected to reverse combustion until the second vertical drilling wells 2, 3, 4 along the line are linked with the first horizontal directional drilling well a to form the ignition system, as well as the second horizontal directional drilling well b is subjected to reverse combustion until the third vertical drilling wells 2'-10' along the line are linked with the second horizontal directional drilling well b to form the production wells system; and (II) the rest of second horizontal directional drilling wells c, d, e, f parallel to said one second horizontal directional drilling well b are drilled while the ignition system and the production wells system for gasification furnace are constructed, wherein the horizontal sections of said rest of second horizontal directional drilling wells are located in the coal seam, and the ends of the horizontal sections are directed to the first horizontal directional drilling well a and are communicated with the same by means of pressure air fracturing.

[0066] Owing to the above, the underground coal gasification furnace and the underground coal gasification process according to the present invention have the fol-

lowing features:

- 1) The underground coal gasification furnace has simple structure, wherein respective drilling wells are independent upon each other, and drilling can be performed at the same time, so as to shorten the construction time of the gasification channel and reduce the costs for gasification furnace construction;
- 2) A supporting and protecting arrangement is installed immediately upon one well is finished, so as to further protect the structure stability of the underground coal gasification furnace;
- 3) Compared with gasification in a single horizontal directional drilling well, it is possible to effectively control the fall range of the coal seam roof and prevent groundwater from being polluted by performing gasification in a plurality of horizontal directional drilling wells at the same time;
- 4) A larger combustion surface is formed due to gasification in several rows at the same time. Therefore, the heat loss of the gasification furnace will be reduced and the recovery and gasification efficiency of coal will be increased;
- 5) Retreat gasification in drilling wells at the same time makes it easier to control the movement of the combustion zone, in particular the gasification based on the gasifying agent is pure oxygen, such as pure oxygen-water vapour, pure oxygen-carbon dioxide, pure oxygen-water vapour-carbon dioxide;
- 6) The mode of combination of vertical drilling wells and horizontal drilling wells in the present invention can realize gas injection in large amount, gas production in large amount and further realize a large-scale production of underground coal gasification.

[0067] The underground coal gasification furnace according to the present invention is characterized in the following operation features: linking the drilling wells separated from each other; the coal seam is ignited from the ignition system; the production wells system and the gas injection system are communicated by reverse combustion, and then the gasifying agent is injected into the gas injection system by means of the coiled tubing; and coal gas is produced through the production wells system; reverse combustion or retreat gasification are performed to realize a large-scale production of underground coal gasification. It is better that the vertical drilling wells in rows (such as the second vertical drilling wells 2-6) are in the direction of the cracks development in coal seam; it is better to drill the horizontal directional drilling wells (e.g., the first horizontal directional drilling well a in the examples 1-4) to form ignition system in the direction against the cracks development in coal seam; at the beginning of construction of gasification furnace, the production wells system and the gas injection system can be communicated with the ignition system or not. The drilling wells can be better protected against blockage when they are not communicated; there is a certain dis-

tance from the ignition system; this distance is rough estimated according to the semi diameter of the channel after reverse combustion and the length of the developed cracks in the heated coal seam. It is necessary to install a bore protect arrangement in the nude section in the coal seam in time when one well have been drilled, said protect arrangement may be seam pipes or seamless pipes made of cast iron, PVC, combustible composite materials, or glass fiber reinforced plastic, preferably seamless glass fiber reinforced plastic pipe; gasification is performed in a plurality of horizontal directional drilling wells (such as a plurality of second horizontal directional drilling wells in the examples 1-4) at the same time, and it is better to use retreat gasification or reverse combustion; retreat gas injection is preferably a retreat gas injection by means of coiled tubing, and the gasified coal gas is exhausted to the ground through a common production wells system; the timing when the coiled tubing is drawn back is determined according to the obvious variation of the contents of the effective components in coal gas. Obviously, the underground coal gasification furnace and the underground coal gasification process according to the present invention can improve the structure of the gasification furnace as well as increase the stability during gasification operation; before implementing gasification, respective drilling wells are independent, and have the supporting and protection arrangement so that they do not easily fall. The retreat gasification can prevent the contact between the gasifying agent and the coal seam from being interrupted due to roof fall, so as to solve the problem of unstable structure of the underground coal gasification furnace as well as the unstable gasification operation. Furthermore, the present invention realizes the costs reduction for a large-scale production, the number of bore holes in the coal seam per unit area is suitable, the costs for gasification furnace construction is relative low; the recovery efficiency of coal seam and coal gas yield may be increased due to parallel gasification in a plurality of rows, the heat loss is reduced, the risk of groundwater influx into the combustion zone is reduced. That is, the problem restricting the underground coal gasification production in large-scale has been solved, and reduce coal gas production costs at the same time.

[0068] The numerical values referred to in the present invention defined by the word "about" include themselves. The numerical values and amounts referred to in the present invention are examples instead of limitations and they can be adjusted in practical situation. The coiled tubing is also an example, and it may be any gasifying agent introduction pipe in fact, as long as its gas injection end can be moved when the gasifying agent introduction pipe is towed so as to guide the movement of the combustion zone in the drilling having this gasifying agent introduction pipe. The definition "until ... the vicinity of the coal feeding point" referred to in the present invention indicates that it is possible to move towards the coal feeding point until arriving at the desirable termination posi-

tion.

Claims

1. An underground coal gasification furnace, comprising:
 - an ignition system having a first vertical drilling well (1) entering into coal seam, and a first horizontal directional drilling well (a) with a horizontal section in the coal seam and in communication with the first vertical drilling well (1);
 - a gas injection system having a second drilling well entering into the coal seam and in communication with the first horizontal directional drilling well (a),
 wherein, the second drilling well is at least one second horizontal directional drilling wells (b, c, d, e, f) with a horizontal section in the coal seam.
2. The underground coal gasification furnace according to claim 1, wherein, the first horizontal directional drilling well (a) is communicated with the second horizontal directional drilling wells (b, c, d, e, f) by means of reverse combustion.
3. The underground coal gasification furnace according to claim 1, wherein, the second drilling wells are at least two second horizontal directional drilling wells (b, c, d, e, f) parallel to each other, which are arranged on one side or on both sides of the first horizontal directional drilling well (a) in the direction of intersecting the first horizontal directional drilling well (a).
4. The underground coal gasification furnace according to claim 3, wherein, the second horizontal directional drilling wells (b, c, d, e, f) forms an angle of 30° -90° with the first horizontal directional drilling well (a).
5. The underground coal gasification furnace according to any one of claims 1-4, wherein, at least one second vertical drilling wells (2, 3, 4, 5, 6) is disposed along the first horizontal directional drilling well (a), wherein all of the second vertical drilling wells are in communication with each other by means of reverse combustion of the first horizontal directional drilling well (a) to form a gas production well.
6. The underground coal gasification furnace according to claim 5, wherein, the end of the horizontal section of the first horizontal directional drilling well (a) is communicated with the first vertical drilling well (1) by means of combustion penetration or directional blasting or cold-state fracturing.

7. The underground coal gasification furnace according to claim 5, wherein, the end of the horizontal section of the first horizontal directional drilling well (a) is communicated with the first vertical drilling well (1) directly.
8. The underground coal gasification furnace according to claim 1, wherein, the second drilling wells are at least two second horizontal directional drilling wells (b, c, d, e, f), which are arranged on the same side of the first horizontal directional drilling well (a), wherein one second horizontal directional drilling wells (b, c, d, e, f) is directed to and is communicated with the first vertical drilling well (1) by means of fracturing penetration; and at least one third vertical drilling wells (2', 3', 4', 5', 6', 7', 8', 9', 10') is arranged along said one second horizontal directional drilling well, wherein said one second horizontal directional drilling well is communicated with the third vertical drilling wells (2', 3', 4', 5', 6', 7', 8', 9', 10') by means of reverse combustion and form together the gas production wells.
9. The underground coal gasification furnace according to any one of claims 1-4, 6-8, wherein, the nude section of each of all drilling wells located in the coal seam is supported and protected by a supporting and protection arrangement.
10. The underground coal gasification furnace according to claim 9, wherein, the supporting and protection arrangement is a sieve pipe or seamless pipe.
11. The underground coal gasification furnace according to claim 1, wherein, a towable gasifying agent-introduction pipe is at least arranged in one of said second horizontal directional drilling wells (b, c, d, e, f), the gas injection end of which moves when the gasifying agent-introduction pipe is towed.
12. An underground coal gasification process, comprises:
- the step of constructing an underground coal gasification furnace according to any one of the preceding claims 1-11; and
 - the step of performing gasification in the constructed gasification furnace, comprising: guiding the combustion zone of the first horizontal directional drilling well (a) to retreat in the second horizontal directional drilling wells (b, c, d, e, f) until back to the vicinity of the coal feeding point of the second horizontal directional drilling wells (b, c, d, e, f).
13. The underground coal gasification process according to claim 12, wherein, the step of constructing an underground coal gasification furnace includes the following sub-steps 1-2, which are performed sequentially:
- the sub-step 1: the following drilling wells are drilled one after another: a first vertical drilling well (1) entering into the coal seam, a first horizontal directional drilling well (a) with a horizontal section in the coal seam, at least two second vertical drilling wells (2, 3, 4, 5, 6) arranged along the first horizontal directional drilling well (a), and at least two second horizontal directional drilling wells (b, c, d, e, f) arranged on one side or on both sides of the first horizontal directional drilling well (a) and having a horizontal section in the coal seam, wherein all these drilled drilling wells are separated from each other; and
 - the sub-step 2: firstly communicating the first horizontal directional drilling well (a) with the first vertical drilling well (1), and then igniting the coal seam at the bottom of the first vertical drilling well (1), injecting gasifying agent from the first horizontal directional drilling well (a), guiding the movement of the combustion zone to perform reverse combustion to the first horizontal directional drilling well (a), until realizing the communication with the rest of drilling wells in the sub-step 1.
14. The underground coal gasification process according to claim 13, wherein, the pressure air is introduced into the second horizontal directional drilling wells (b, c, d, e, f) while the first horizontal directional drilling well (a) is subjected to reverse combustion, wherein the pressure of the pressure air is greater than that in the first horizontal directional drilling well (a).
15. The underground coal gasification process according to claim 13, wherein, the guiding the movement of the combustion zone in the sub-step 2 is realized by towing the coiled tubing in the first horizontal directional drilling well (a) to make its gas injection end move.
16. The underground coal gasification process according to claim 13, wherein, the first horizontal directional drilling well (a) is drilled towards the first vertical drilling well (1) against the developing direction of cracks in coal seam.
17. The underground coal gasification process according to claim 12, wherein, the step of constructing an underground coal gasification furnace includes the following sub-steps 1-3, which are performed sequentially:
- the sub-step 1: the first vertical drilling well (1) and at least two second vertical drilling wells (2,

3, 4, 5, 6) are drilled successively in the developing direction of cracks in coal seam, which enter into the coal seam and are separated from each other, and then the first horizontal directional drilling well (a) is drilled against the developing direction of cracks in coal seam towards the direction of the first vertical drilling well (1), the first horizontal directional drilling well (a) communicates the first vertical drilling well (1) and some of the second vertical drilling wells (2, 3, 4, 5, 6) in the coal seam;

- the sub-step 2: at least two second horizontal directional drilling wells (b, c, d, e, f) are drilled on one side of the first horizontal directional drilling well (a), wherein the ends of said at least two second horizontal directional drilling wells are directed to the first horizontal directional drilling well (a), wherein the end of some second horizontal directional drilling wells (b, d, f) is communicated with the first horizontal directional drilling well (a), and the end of the other second horizontal directional drilling wells (c, e) keeps a certain distance from the first horizontal directional drilling well (a);

- the sub-step 3: the coiled tubing is inserted into the first horizontal directional drilling well (a), and the gasifying agent is injected into the first horizontal directional drilling well (a) through the coiled tubing, igniting the coal seam at the bottom of the first vertical drilling well (1), the coiled tubing is towed to guide the movement of the combustion zone to perform reverse combustion in the first horizontal directional drilling well (a), until the other second horizontal directional drilling wells (c, e) and the other second vertical drilling wells (2, 3, 4, 5, 6) are communicated with the first horizontal directional drilling well (a).

18. The underground coal gasification process according to claim 17, wherein, the sub-step 2 further comprises:

- a fourth vertical drilling wells (1", 2", 3", 4", 5") are drilled into the coal seam on one side of the first horizontal directional drilling well (a), and are respectively communicated with the second horizontal directional drilling wells (b, c, d, e, f) in one-to-one manner,

- when the combustion zone in the second horizontal directional drilling well moves to the bottom of the fourth vertical drilling wells (1", 2", 3", 4", 5"), the fourth vertical drilling wells (1", 2", 3", 4", 5") are used as gas production wells instead of the first vertical drilling well (1), the second vertical drilling wells (2, 3, 4, 5, 6) and the first horizontal directional drilling well (a) during the gasification in the constructed gasification furnace.

nace.

19. The underground coal gasification process according to claim 13, wherein, the other second horizontal directional drilling wells (b, c, d, e, f) are used as gas production wells, when the gasifying agent introduction pipe in some second horizontal directional drilling wells (b, c, d, e, f) is towed to move the combustion zone,

wherein the gasifying agent introduction pipe in the other second horizontal directional drilling wells (b, c, d, e, f) is drawn out when these second horizontal directional drilling wells (b, c, d, e, f) are used as gas production wells, the first horizontal directional drilling well (a), the first vertical drilling well (1) and the arranged second vertical drilling well are closed.

20. The underground coal gasification process according to claim 12, wherein, the step of constructing an underground coal gasification furnace includes:

- (I) to construct an ignition system and production wells system for gasification furnace by means of the following way: the following drilling wells entering into the coal seam are drilled one after another: the first vertical drilling well (1); the first horizontal directional drilling well (a) and one second horizontal directional drilling well (b) which are perpendicular to each other and have the horizontal section in the coal seam; a second vertical drilling wells (2, 3, 4, 5, 6) and a third vertical drilling wells (2', 3', 4', 5', 6', 7', 8', 9', 10'), which are respectively arranged crosswise along these two horizontal directional drilling wells; then these two horizontal directional drilling wells are communicated with the first vertical drilling well (1) through fracturing, and then the first horizontal directional drilling well (a) is subjected to reverse combustion until the second vertical drilling wells (2, 3, 4, 5, 6) along the line are penetrated to form the ignition system, as well as the second horizontal directional drilling well (b) is subjected reverse combustion until the third vertical drilling wells (2', 3', 4', 5', 6', 7', 8', 9', 10') along the line are penetrated to form the production wells system; and

- (II) the rest of second horizontal directional drilling wells (c, d, e, f) parallel to said one second horizontal directional drilling well (b) are drilled while the ignition system and the production wells system for gasification furnace are constructed, wherein the horizontal sections of said rest of second horizontal directional drilling wells are located in the coal seam, and the ends of the horizontal sections are directed to the first horizontal directional drilling well (a) and are communicated with the same by means of pressure air fracturing.

21. The underground coal gasification process according to claim 20, wherein, the reverse combustion is realized in the following manner: igniting the coal seam in the first vertical drilling well (1), towing the gas injection end of the coiled tubing in the first horizontal directional drilling well (a) and said one second horizontal directional drilling well (b) to guide the combustion zone to move along these two horizontal directional drilling wells to realize reverse combustion.

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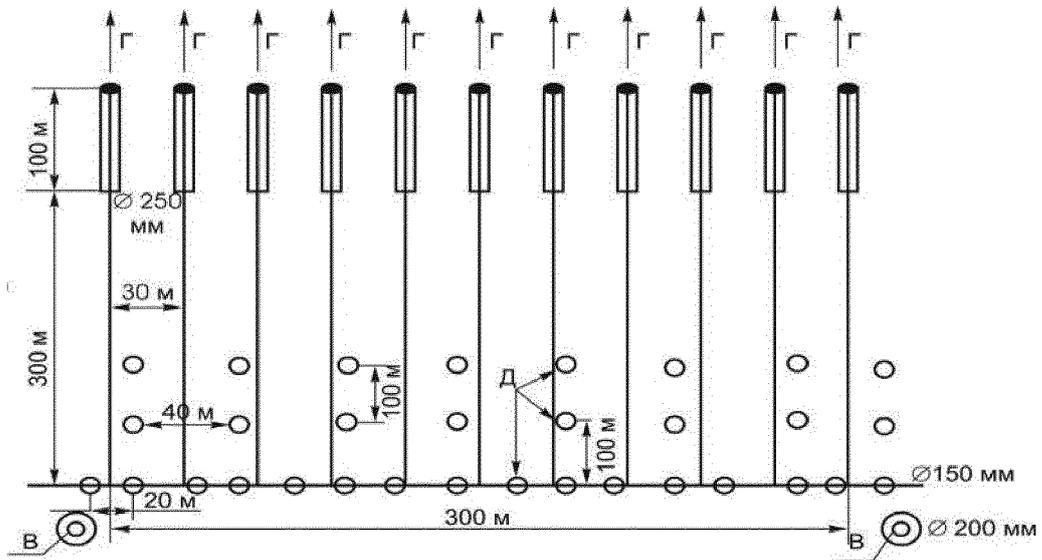


Fig. 1

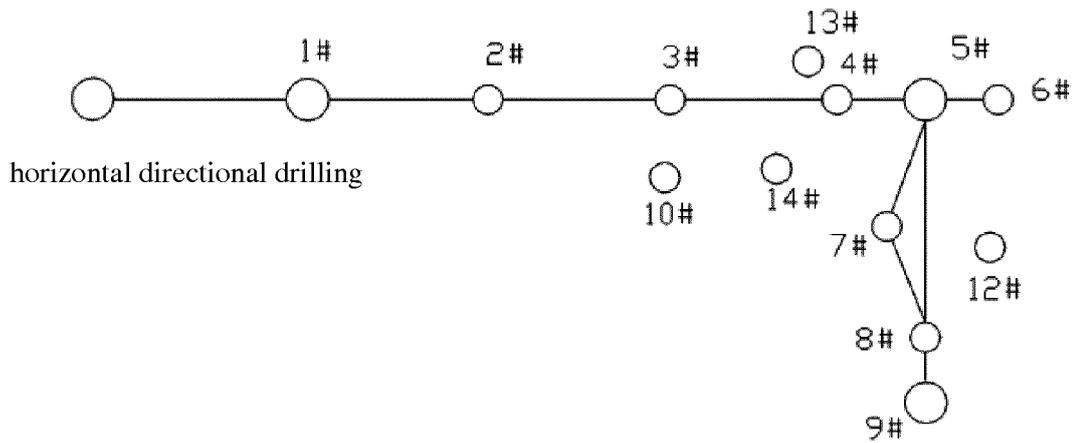


Fig. 2

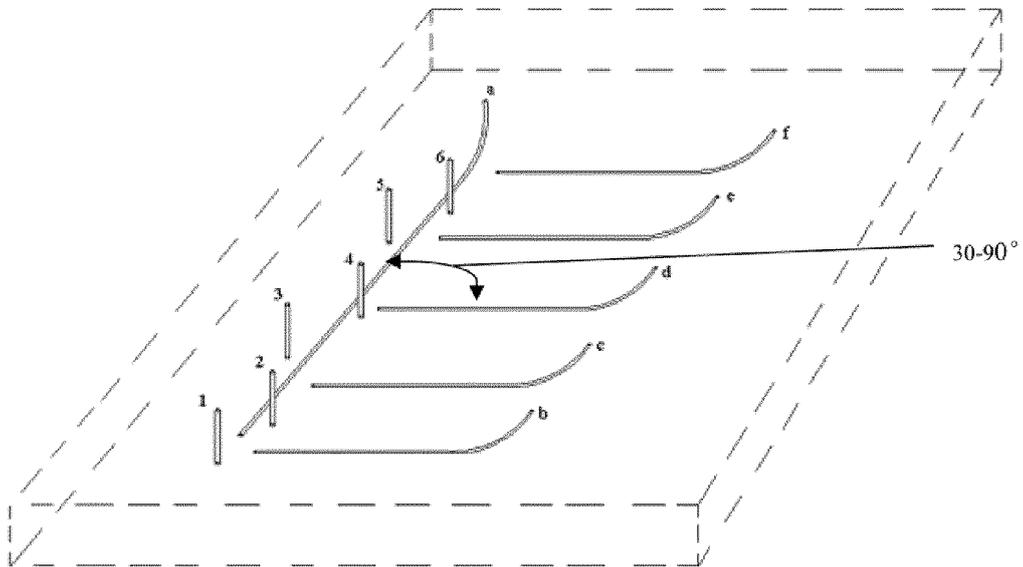


Fig. 3

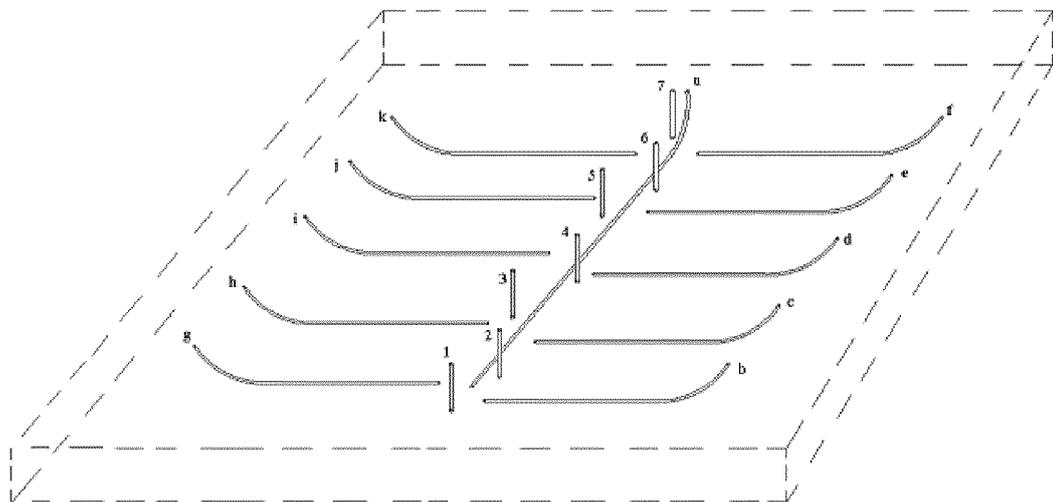


Fig. 4

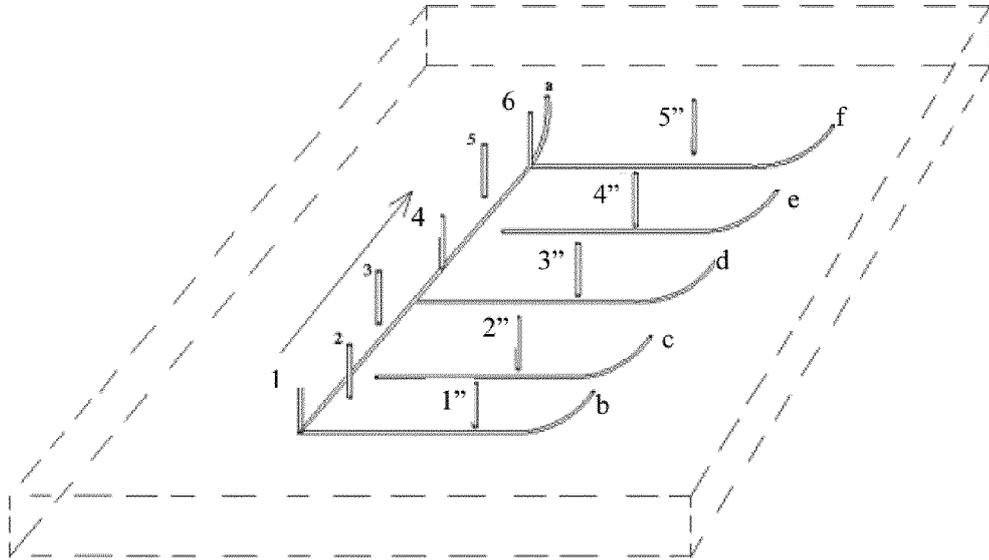


Fig. 5

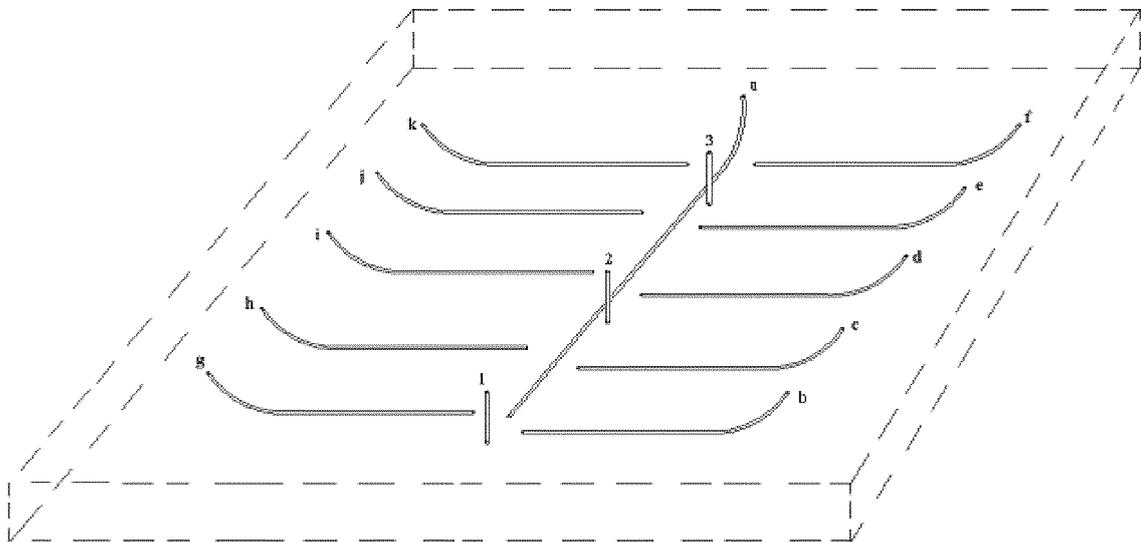


Fig. 6

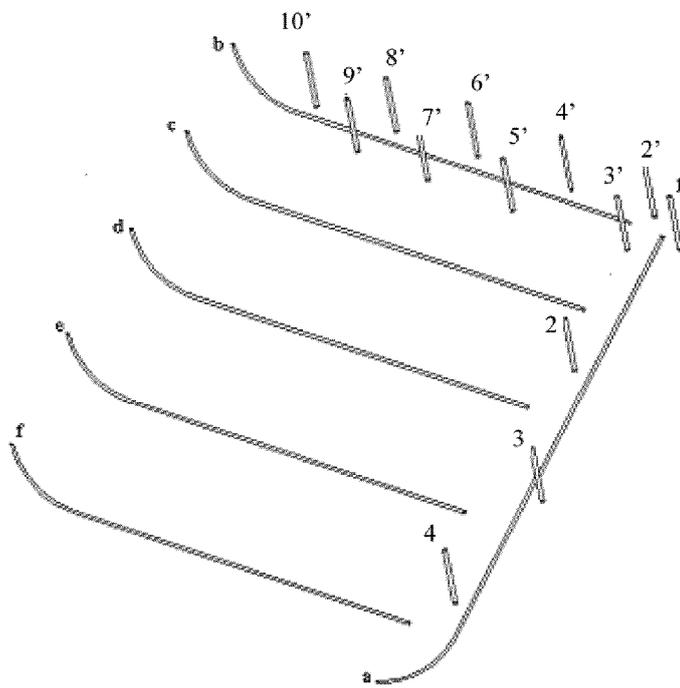


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2014/074721

5	A. CLASSIFICATION OF SUBJECT MATTER	
	E21B 43/295 (2006.01) i	
	According to International Patent Classification (IPC) or to both national classification and IPC	
10	B. FIELDS SEARCHED	
	Minimum documentation searched (classification system followed by classification symbols)	
	E21B; E21C	
15	Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched	
	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)	
	EPODOC, WPI, CNPAT, CNKI: coal, underground, gasfi+, drill+, inject+, ignite+, vertical, horizontal, lateral	
20	C. DOCUMENTS CONSIDERED TO BE RELEVANT	
	Category*	Citation of document, with indication, where appropriate, of the relevant passages
		Relevant to claim No.
25	X	AU 2012101716 A4 (LINC ENERGY LTD) 10 January 2013 (10.01.2013) description, paragraphs [0052]-[0073], and figures 1 and 2
	PX	CN 103437748 A (ENN COAL GASIFICATION MINING CO LTD) 11 December 2013 (11.12.2013) claims 1-21, and figures 1-7
	A	CA 2621013 A1 (BLOOMER CHRIS; AYASSE CONRAD; WU JESSICA) 13 August 2009 (13.08.2009) description, page 12, line 15 to page 21, and figures 1-5
30	A	CN 101864941 A (DENG, Huirong) 20 October 2010 (20.10.2010) description, paragraph f00051, and figure 2
	A	CN 102418476 A (GUODING DALIAN INVEST CO LTD) 18 April 2012 (18.04.2012) description, paragraphs [0029]-[0033], and figures 1 and 2
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35	<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.	
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55	Name and mailing address of the ISA State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No. (86-10) 62019451	Authorized officer ZHANG, Binghua Telephone No. (86-10) 62085426

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INTERNATIONAL SEARCH REPORT
Information on patent family members

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REFERENCES CITED IN THE DESCRIPTION

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