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Kennel et al.

(54) **METHANE ENHANCED LIQUID PRODUCTS RECOVERY FROM WET NATURAL GAS**

(71) Applicants: **Elliot B. Kennel**, Beavercreek, OH (US); **James E. Smith**, Bruceton Mills, WV (US)

(72) Inventors: **Elliot B. Kennel**, Beavercreek, OH (US); **James E. Smith**, Bruceton Mills, WV (US)

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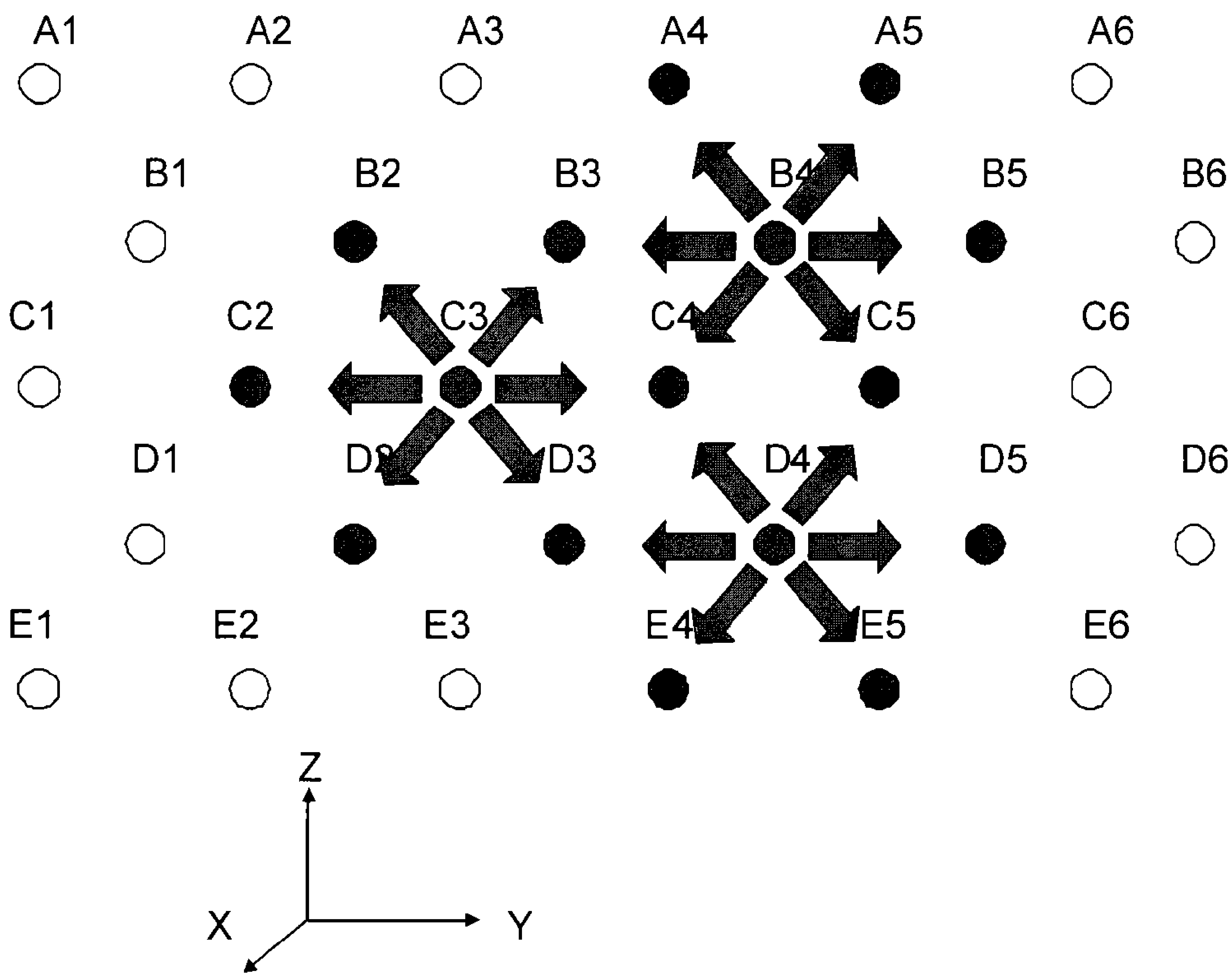
(57) **ABSTRACT**

A process is described for enhancing the yield of liquid products from natural gas from at least one extraction well. This process is achieved by injecting methane at a higher pressure than the rock pressure in at least one injection well site. The methane serves to maintain the pressure of gas in the formation, while also promoting the flow of liquid products away from the injection well and towards a collection well. The net effect is higher net yield of liquid products (referred to as "Y-Grade" liquids) from that well, with lower net yield of non-condensable methane. Because methane is naturally present in natural gas, the gas remaining underground is still a valuable product that can be trapped in the future. The use of the dry gas as the fracturing medium reduces or potentially eliminates the need to use water in fracturing process.



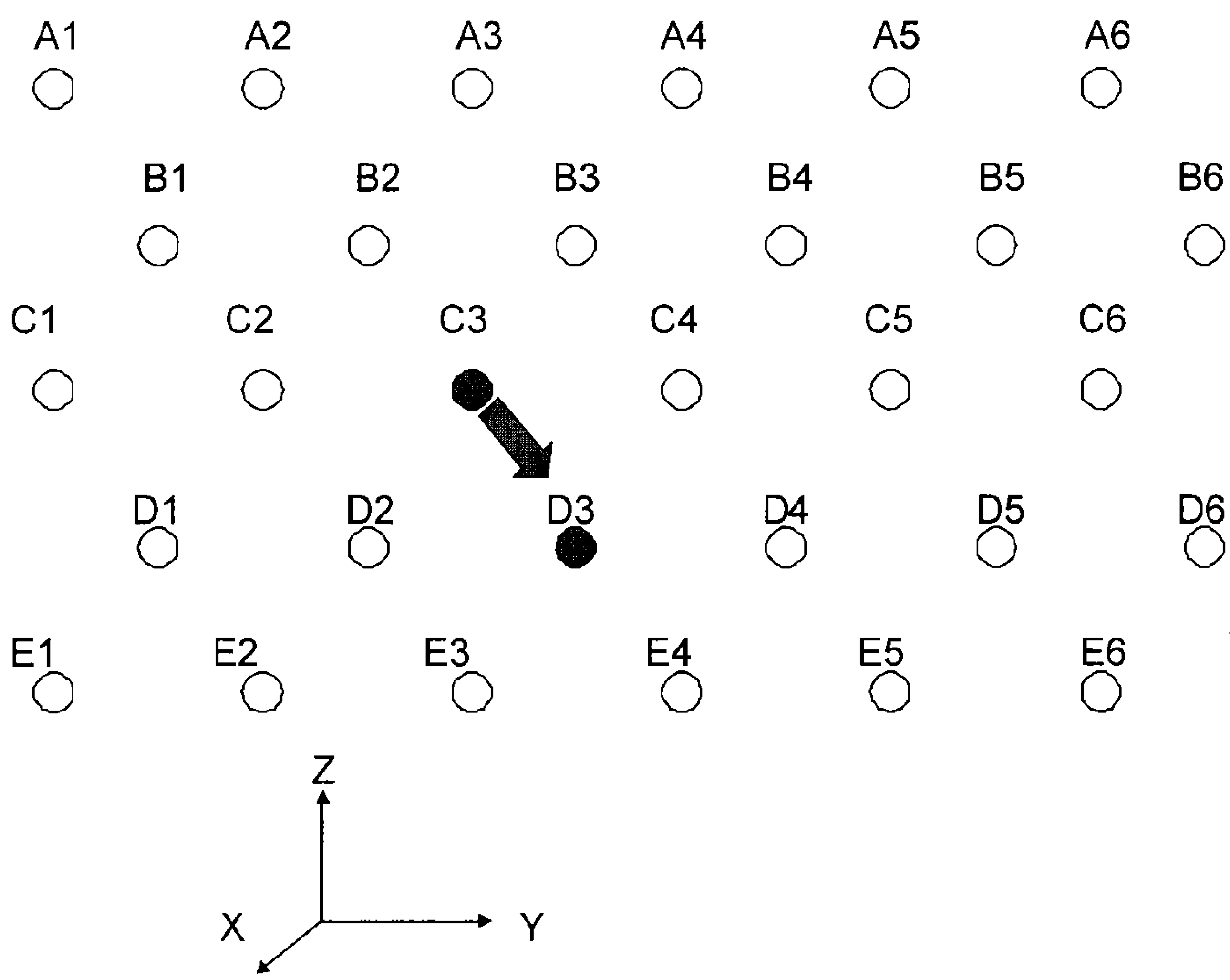

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FIG. 1

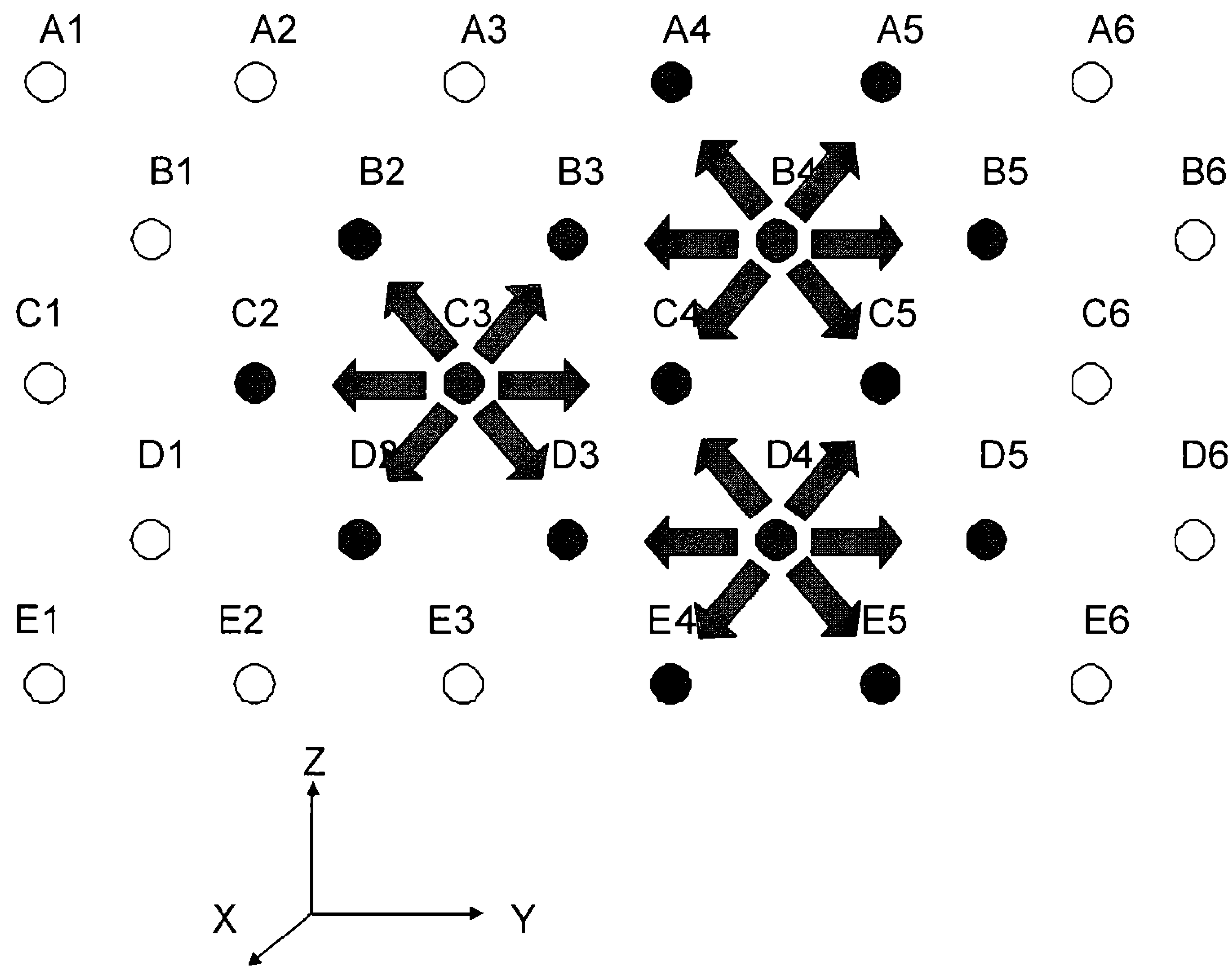
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FIG. 2

METHANE ENHANCED LIQUID PRODUCTS RECOVERY FROM WET NATURAL GAS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application No. 61/816,426, filed Apr. 26, 2013, which is herein incorporated by reference in its entirety.

FIELD OF INVENTION

[0002] This application relates to the recovery of enhanced liquid products from wet natural gas. In particular, it relates to processes for the selective removal of hydrocarbon gas liquid products using minimal hydraulic fracturing liquids, while leaving methane and other dry gas constituents underground, so that the gases and liquids can be available in the future.

BACKGROUND

[0003] The advent of natural gas rich in liquid (commonly referred to as wet gas) represents a shift in American energy production. Hydrofracturing is an available process for increasing the availability of natural gas.

[0004] A generic example of a hydrofracturing process is described herein. A large well pad is constructed to accommodate emergency, maintenance, and construction equipment necessary for the life of the well. After the completion of the well, pad workers install a conductor casing. For example, the casing can be 20 to 50 feet long. This assists in circulating the well fluid and provides the surface with stability to not collapse once the rig is placed on top of it. The casing is, for example, two feet in diameter. Once drilled and the casing is set, the well is cemented. Inside the conductor casing and below a surface casing, sections, such as 40 foot sections for example, are installed to protect aquifers from contamination.

[0005] Vertical and horizontal drilling may be initiated upon the completion of an adequate casing. Perforation is necessary once the drill direction is parallel to the shale rock and at the correct distance. This process creates small holes through the casing, cementing, and other barriers. Small, electrical charges are lowered into the well which, when ignited, eliminate the barrier between the well and rock and allow the flow of natural gas to occur.

[0006] Upon completion of the perforations, hydrofracturing (also known as hydraulic fracturing, hydrofracking, or fracking) is used to increase the permeability of gas-containing rock, which is often shale. This process involves injecting high pressure fluid, into the gas-containing rock strata to fracture the rock, thus creating a network of cracks and fissures in the rock. Sand or other material is used to collect in these fissures, thus preventing them from closing and re-sealing themselves once the water is withdrawn. The water used in hydrofracturing can contain contaminants, and thus will likely be re-used for additional hydrofracturing operations, stored, or taken back to the surface to be remediated.

[0007] Condensate wells refer to extraction wells that contain natural gas, as well as a liquid condensate. This condensate is a liquid hydrocarbon mixture that is often separated from the natural gas either at the wellhead, or during processing of the natural gas.

[0008] Wellheads manage extraction of hydrocarbons while preventing blowouts. A wellhead consists of three pieces of equipment mounted at an opening of a well: a casing head, a tubing head, and a complex valve assembly (often referred to as a "Christmas tree"). The casing heads serve to support the entire length of casing that is run down the well. The tubing head acts much like the casing head, providing a seal between tubing running inside the casing and the surface. The valve assembly sits on top of the tubing and casing heads. The valve assembly contains tubes and valves to control the flow of hydrocarbons and other fluids out of the well. Gas will work towards the surface provided that proper drilling has removed the barriers resting between the gas and head.

[0009] In the early stages of production, engineers can determine the "MER" or most efficient recovery rate, based on the maximum amount of natural gas that can be produced at the well head in a 24-hour period. Engineers can also estimate a "decline rate" based on the change in pressure over time to determine how long a well can economically produce natural gas.

[0010] Artificially created fractures are likely to close under the enormous pressure encountered underground. As an example, many formations exhibit about a pound per square inch of overburden for every foot of depth. Hence shale formations at depths of 3,000 to 10,000 feet often require pressures of 3,000 to 10,000 pounds per square inch to successfully carry out hydraulic fracturing.

[0011] While hydrofracturing is widely used, there are a number of significant drawbacks to hydrofracturing, including prohibitive costs associated with the tremendous water usage required for hydrofracturing. Environmental contamination is a major concern. Also, truck traffic resulting from the need to supply large quantities of water and other resources to a hydrofracturing site may be a concern. Therefore, an improved way is needed to gather natural gas using reduced quantities of hydraulic fracturing liquids.

[0012] Other issues arise from the composition of shale gases. For example, shale gas often contains methane and numerous other contaminants, such as nitrogen and carbon dioxide that require processing and handling. Below is a table showing an example of the breakdown of components of shale gases from several formations:

TABLE 1

Representative Shale Gas Compositions

Component	Composition of Shale Gas Before Processing (Approximate Volume %)			
	Marcellus	Appalachian	Haynesville	Eagle Ford
Methane %	97.131	79.084	96.323	74.596
Ethane %	2.441	17.705	1.084	13.824
Propane %	0.095	0.666	0.205	5.425
Carbon %	0.014	0.034	0.203	4.462
Hexanes %	0.001	0.000	0.061	0.478
Carbon Dioxide %	0.040	0.073	1.816	1.536
Nitrogen %	0.279	2.537	0.369	0.157
Total Inerts	0.318	2.609	2.184	1.693
HHV (BTU/SCF)	1,031.6	1,133.2	1,009.8	1,307.1
Hydrocarbon Dew Point (° F.)	−96.8	−41.3	9.7	119.6
Wobbe Number (BTU/SCF)	1,367.1	1,397.0	1,302.1	1,490.0

[0013] In addition to requiring processing to separate its many components, these gases often are transported via pipelines to other locations for processing. However, many experts contend that the pipeline capacity will be exceeded for natural gas in the Utica Shale area (Ohio, Pennsylvania, and West Virginia). Thus, there is a need for additional ways to process such gases without relying on the limited number of pipelines for transportation.

[0014] Moreover, the character of the combustible components of natural gas varies widely. Liquid products such as butane, propane, can be compressed, liquefied and transported via tanker truck, rail, barge or other means to refineries and chemical plants. For others, like methane, it may be preferable to leave methane underground for future generations to utilize.

[0015] A new process to recover liquid products from wet natural gas is needed. In particular, a process is needed for the selective removal of hydrocarbon gas liquid products using minimal fracturing liquids, while leaving dry gas constituents in the ground that can be recovered in the future.

BRIEF SUMMARY OF INVENTION

[0016] This disclosure describes a process for obtaining liquid products from natural gas while storing gaseous products, such as methane, underground. It is especially pertinent to gas present in low permeability shale formations, in which the shale normally needs to be fractured in order to obtain flow of gas into a collection well. However, this process may also be performed in shale formations with higher permeability. This can be achieved by using high pressure fluid with additives to create fractures in the rock formation. After pumping out the fluid, these additional fractures within the formation allow gas to flow more freely to the at least one extraction well.

[0017] In an embodiment, a method for increasing and maintaining the permeability of a fractured rock formation comprises forming at least one injection well through a fractured rock formation; injecting and flowing a high pressure gas into the at least one injection well over a predetermined time scale; permeating the fractured rock formation with an injected gas flow in the same direction as the high pressure gas; and collecting the high pressure gas in one or more extraction wells, while extracting additional liquid and gas products from the extraction wells.

[0018] Fractures in the fractured rock formation may be produced by hydraulic fracturing using a working fluid, followed by injecting the high pressure gas over a predetermined time scale of not less than one week and as long as 30 years, to maintain the permeability created via the hydraulic fracturing process. In another embodiment, the predetermined time scale may be approximately thirty minutes, one hour, six hours, twelve hours, etc.

[0019] The working fluid may be chosen from at least one of the following: non-aqueous liquid, water, brine, polymers, carbon dioxide, methane, or a combination of these working fluids. The working fluid may include 95% or more of the following: methane, ethane, or a combination thereof.

[0020] Cracks and fissures in the fractured rock formation may be created exclusively from a high pressure working fluid. The collected high pressure gas may be separated to remove methane from liquid fractions obtained from extracted natural gas.

[0021] In an embodiment, the methane may be compressed to a higher pressure than the well bottom pressure of the extraction well and then injecting or reinjecting the methane into a gas-bearing area of the fractured rock formation; and then the methane may be blended with natural gas stored inside a porous area of the fractured rock formation.

[0022] Pressure in the extraction well may be increased by injecting a non-condensable gas at a pressure higher than the pressure in the extraction well, and creating an overburden pressure at the bottom of the extraction well that increases the rate of natural gas extraction.

[0023] In an embodiment, a method for increasing permeability of a rock formation containing natural gas may include forming at least two boreholes in a rock formation, wherein a first borehole is externally pressurized with a working fluid to a level of at least 1,000 psi above the pressure of the rock formation and a second borehole is pressurized at a level below the pressure of the rock formation, such that the working fluid pressure differential is sufficient to cause fracturing in the rock formation between the first and second boreholes, and the working fluid flows from one borehole to the other.

[0024] Further, the external pressurization may be decreased and any residual natural gas is extracted from the first and second boreholes. In another embodiment, a working fluid may be transferred or moved from the first borehole to the second borehole, causing any additional residual natural gas from the rock formation, including liquid constituents of natural gas, to flow into the second borehole. Subsequently, the liquid constituents extract natural gas from the second borehole. An external pressurization may be applied intermittently to maintain permeability between the first borehole and the second borehole.

[0025] In an embodiment, the working fluid may be composed of a substantially non-aqueous liquid, or a gas chosen from the group including methane, ethane, alkane gases, carbon dioxide, carbon monoxide, nitrogen, natural gas, other reducing gases, inert gases, non-oxidizing gases, or a combination thereof.

[0026] Particles from the working fluid may be utilized to maintain permeability in the rock formation.

[0027] In an embodiment, a method for increasing the permeability of a rock formation containing natural gas may include the steps of forming at least two boreholes, wherein a first borehole is externally pressurized with a working fluid, and surrounding boreholes are pressurized; and increasing the porosity in an outward direction of a rock formation between the first borehole and the surrounding boreholes, wherein the first borehole is externally pressurized with a working fluid to a level of at least 1,000 psi above the rock pressure and the surrounding boreholes are either maintained or below the over burden pressure, such that the working fluid pressure differential is sufficient to cause fracturing in the rock formation between the surrounding boreholes and the working fluid flows from one borehole to another.

[0028] Pressurization may be applied intermittently in order to maintain permeability in a preferred direction, between the first borehole and the second borehole.

[0029] The working fluid may include particles to partially fill cracks in the rock formation and maintain permeability in a preferred direction in the rock formation. The working fluid may be a gas, such as methane, ethane, carbon dioxide, nitrogen, a higher alkane compound, or a combination thereof. In an embodiment, the working fluid may further include antimicrobial materials.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The present disclosure may be better understood by reference to the following detailed description taken in connection with the following illustrations, wherein:

[0031] FIG. 1 is a perspective view of an array of boreholes in one embodiment; and

[0032] FIG. 2 is a perspective view of an array of boreholes in another embodiment.

DETAILED DESCRIPTION

[0033] Reference will now be made in detail to exemplary embodiments of the described herein. It is to be understood that other embodiments may be utilized and structural and functional changes may be made without departing from the respective scope of the disclosure. Moreover, features of the various embodiments may be combined or altered without departing from the scope of the disclosure. As such, the following description is presented by way of illustration only and should not limit in any way the various alternatives and modifications that may be made to the illustrated embodiments and still be within the spirit and scope of the disclosure.

[0034] A "fractured rock formation" may include one or more hydrocarbon containing layers, one or more non-hydrocarbon layers, an overburden, and/or an underburden. "Hydrocarbon layers" refer to layers in the formation that contain hydrocarbons. The hydrocarbon layers may contain non-hydrocarbon material and hydrocarbon material. The "overburden" and/or the "underburden" may include one or more different types of impermeable materials. For example, the overburden and/or underburden may include rock, shale, mudstone, or wet/tight carbonate. In some embodiments of in situ heat treatment processes, the overburden and/or the underburden may include a hydrocarbon containing layer or hydrocarbon containing layers that are relatively impermeable and are not subjected to temperatures during in situ heat treatment processing that result in significant characteristic changes of the hydrocarbon containing layers of the overburden and/or the underburden. For example, the underburden may contain shale or mudstone, but the underburden is not allowed to heat to pyrolysis temperatures during the in situ heat treatment process. In some cases, the overburden and/or the underburden may be somewhat permeable.

[0035] A process for recovery of enhanced liquid products from wet natural gas is described. In one embodiment, the process obtains higher alkanes as liquid condensates and the remaining dry gas may be returned to the ground at least one injection well.

[0036] A portable and reusable mobile well pad may be constructed at sites. An injection site can be collocated with one or more extraction wells, with each well with about 150 to 500 feet of one another, although other distances between wells may be used, depending on the characteristics of the site. One or more of the wells may optionally be hydrofractured.

[0037] A non-condensable gas, such as methane, may be injected at a pressure higher than the pressure in the extraction well, and preferably higher than the overburden pressure. In the case of methane, the injected methane will flow from the at least one injection well towards the extraction wells, and by doing so, it maintains the gaps in fractures in the rock between the injection well and extraction well. This allows natural gas contained in the formation to permeate the rock and travel up through the fractures and towards the extraction well. Although methane and non-condensable gases are exemplified, other materials and combinations of any materials may be used as an injection fluid.

[0038] The extraction well may be filled with gas from the at least one injection well and mixes with gas permeating from the formation. The increased mass flow rate results in higher pressure at the extraction well and thus in more efficient wet gas collection.

[0039] The use of at least one injection well or wells with an injection fluid may not necessarily increase the total net yield of natural gas from the overall formation. It may however result in a higher yield of condensable liquids, which are displaced from the formation by an injected fluid. Gas remaining in the formation may therefore have a higher content of methane compared to other natural gas constituents. This process may allow for a significant reduction or total elimination of water as the fracking medium.

[0040] Methane may be used to form an injection gas because it does not dilute natural gas in the formation. If a non-combustible gas were used, such as carbon dioxide or nitrogen, then it may need to be removed if the remaining gas in the formation were to be used in the future.

[0041] After the gas pressure in the well decreases, the well generates less natural gas per unit time, and the value of the well may also decrease. In some cases, the gas pressure within the formation may tend to equalize over a period of time, so that wells which appear to be empty may, after a period of, for example, weeks to years, once again become productive. There could be little to no use of at least one injection well during the waiting period for the rock formation pressure to equilibrate. This is another reason why it may be desirable to operate the at least one injection well intermittently rather than continuously over the lifetime of the surrounding injection wells.

[0042] This process serves at least three improved functions. First, injection of a working fluid, such as methane, serves to maintain the permeability of a hydraulically fractured shale formation, therefore preventing fractures from closing or overcoming the tendency to plug.

[0043] Second, injection of a working fluid, such as methane, can be used as a substitute for hydraulic fracturing, and thus increase the permeability of rock formations by physically fracturing rock in the gas-containing formation, thus avoiding to some extent, the high cost, environmental complexity, and other drawbacks associated with injecting high pressure water into the formation and later pumping it out and reclaiming the water. This can be repeated intermittently over the total operating history of the well field. Other gases may be used as the injection fluid; non-limiting examples include a non-aqueous solution, brine, polymers, carbon dioxide, methane, or a combination thereof.

[0044] Third, injection of a working fluid, such as methane, can be used as a means to store methane, while not diluting the formation with non-combustible gas. Hence the methane could potentially be retrieved later on. If, for example, a non-combustible gas were used in the injection well, the stored gas may need to be separated from the non-combustible gas.

[0045] If used at the Utica Shale, for example, this recovery process for methane enhanced liquids products may produce light sweet crude from wet gas while leaving methane and other dry gas constituents in the ground. This process can be implemented with low capital investment, at the drilling site.

[0046] In an embodiment, an extraction well may be drilled into a shale formation, and hydraulic fracturing is used to break up rock surrounding the well casing. A second well, referred to as an injection well may be drilled into the same formation, parallel to the extraction well separated by a distance of, for example, 150 feet to 500 feet, depending on the expected permeability of the shale formation. In one embodiment, the distances can be less than 150 feet or greater than 500 feet, depending on the circumstances of the site. Hydraulic fracturing may be used to break up rock surrounding the well casing of the injection well. Natural gas may be obtained from the extraction well and brought to the surface. At the surface, the natural gas may be separated into a gaseous product, and condensed liquids are removed as "Y-Grade" liquids. Impurities such as carbon dioxide and nitrogen can be removed by processes such as pressure swing absorption, thus resulting in pure methane gas. The methane gas may be injected into the injection well. The pressure of the injection must be higher than the pressure in the extraction well, and preferably higher than the overburden pressure at the well bottom depth. In an embodiment, the injection well pressure will be approximately 1,000 psi higher of the extraction well, and the gas will slowly flow from the injection well toward the extraction well. At the same time, natural gas already present in the shale formation will flow along a path similar to the path of the methane. Thus, the extraction well will produce a blend of natural gas and injected methane from the shale formation. This results in enhanced total yield of Y-Grade liquids, while reducing the net yield of methane. The methane may be left underground, permitting the wells to be capped. The methane can be retrieved later on, as may be desirable depending on, for example, the market price and available infrastructure near the wellhead in the future. These examples are merely representative of a few reasons to access the well at a later time, however, this disclosure is not limited to these examples.

[0047] In another embodiment, an extraction well may be drilled into a shale formation. A second well, referred to as an injection well may be drilled into the same formation, parallel to the extraction well and separated by a distance of, for example 150 feet to 500 feet, depending on the expected permeability of the shale formation. In one embodiment, the distances can be less than 150 feet or greater than 500 feet, depending on the circumstances of the site. Hydraulic fracturing with water may not be used to break up rock surrounding the well casing of either well. Natural gas, either obtained from an outside source or from the extraction well, may be injected in the injection well at a pressure at least 1,000 psi higher than the rock pressure at the bottom of the extraction well, thus creating a path from the injection well to the extraction well and fracturing rocks in the shale formation around that path. At the surface, the natural gas may be separated into a gaseous product, and condensed liquids are removed as "Y-Grade" liquids. Impurities such as carbon dioxide and nitrogen can be removed by processes such as pressure swing absorption, thus resulting in pure methane gas. In an embodiment, the injection well pressure will be maintained at approximately 1,000 psi higher than the pressure of the extraction well, and optionally varied at up to 10,000 psi higher than the rock pressure at the depth of the extraction well, and the gas will slowly flow from the injection well toward the extraction well. In another embodiment, the well pressure will be maintained at any pressure, and can optionally be varied at any pressure. Optionally, the flow can be temporarily reversed by elevating the pressure in the extraction well such that it is higher than the pressure in the injection well, thus inducing additional fractures between the two wells. After a period of approximately an hour to about one month, natural gas already will likely be present in the shale formation and the natural gas will flow along a path similar to the path of the methane. Thus, the extraction well may produce a blend of natural gas and injected methane from the shale formation. This results in enhanced total yield of Y-Grade liquids, while reducing the net yield of methane. The methane may be left underground, permitting the wells to be capped. The methane can be retrieved later on, as may be desirable depending on, for example, the market price and available infrastructure near the wellhead in the future. These examples are merely representative of a few reasons to access the well at a later time, however, this disclosure is not limited to these examples.

[0048] In an embodiment, an extraction well may be drilled into a shale formation, and hydraulic fracturing may be used to break up rock surrounding the well casing. A second well, referred to as an injection well may be drilled into the same formation, parallel to the extraction well and separated by a distance of, for example, 150 feet to 500 feet, depending on the expected permeability of the shale formation. In one embodiment, the distances can be less than 150 feet or greater than 500 feet, depending on the circumstances of the site. Hydraulic fracturing may be used to break up rock surrounding the well casing of the injection well. Natural gas may be obtained from the extraction well and brought to the surface. At the surface, the natural gas may be separated into a gaseous product, and condensed liquids are removed as "Y-Grade" liquids. Impurities such as carbon dioxide and nitrogen can be removed by processes such as pressure swing absorption, thus resulting in pure methane gas. The methane gas may not be injected into the injection well, but is transferred to a pipeline or liquefied for transfer to a user of the methane at the surface. After the natural gas is substantially depleted, methane from an outside source may be injected into the injection well, thus using the injection well and the shale formation as a means of quasi-permanently storing methane from the outside source. The pressure of the injection well must be higher than the pressure in the extraction well, and preferably higher than the overburden pressure at the well bottom depth. In an embodiment, the injection well pressure will be approximately 1,000 psi higher than the pressure of the extraction well.

[0049] In another embodiment, an array of boreholes are drilled into a formation such that the holes become approximately horizontal, such that the axis of the bore forms an angle of 45 degrees or more with respect to the direction of gravity.

[0050] As shown in exemplary FIG. **1**, Borehole C3 may be pressurized, with borehole D3 used to extract gas, thus creating a lower pressure in Borehole D3. The pressure differential between Borehole C3 and Borehole D3 results in cracking the rock formation, especially for example in the vicinity between Borehole C3 and Borehole D3. Then Borehole D3 may then be allowed to return to the equilibrium pressure of the formation such that extraction is halted or diminished. The pressure in an adjacent borehole, such as Borehole C4, may be then lowered so that a permeable path is created between C3 and C4. Then Borehole C4 may be allowed to return to the equilibrium pressure of the formation such that extraction is halted or diminished. The pressure in Borehole B3 may be then lowered to that a permeable path is created between C3 and B3. Then Borehole B3 may be allowed to return to the equilibrium pressure of the formation such that extraction is halted or diminished. The pressure in Borehole B2 may then be lowered so that a permeable path is created between B2 and C3. Then Borehole B2 may be allowed to return to the equilibrium pressure of the formation such that extraction is halted or diminished. The Pressure in Borehole C2 may then be lowered so that a permeable path may be created between C3 and C2. Then the pressure in Borehole C2 may be allowed to return to the equilibrium pressure of the formation such that extraction may be halted or diminished. The Pressure in Borehole D2 may then be lowered so that a permeable path may be created between C3 and D2. The pressure in Borehole D2 may then be allowed to return to the equilibrium pressure of the formation such that extraction may be halted. As an example, the rock pressure of an underground formation may be 3,000 psi to 10,000 psi. Although this range is described, other pressure ranges for the rock pressure may be utilized. The overpressure in the injection borehole may be at least 3,000 psi, and the under pressure in the extraction well may be as close to vacuum as achievable. Methane is an example of a preferred working fluid because it is not a contaminant for natural gas, and moreover avoids the need to combust methane in the near term after it is extracted. Methane can be used to advantageously maintain the pressure in the formation, and can be stored for decades if desired for economic, environmental or other reasons.

[0051] Alternatively, positive pressure in the injection borehole can be supplied with simultaneous reduced pressure extraction from surrounding boreholes, rather than sequential extraction, and an example of which is shown in FIG. **2**.

[0052] It is further the intent of this process to allow the management of the entire well field, by systematically directing the extraction of liquid-rich wet gas in a preferred direction, e.g., from west to east. Other suitable directions may also e utilized.

[0053] There are several possible embodiments of the disclosure, and the possible embodiments are not limited to the examples below, which are presented as examples.

[0054] The process disclosed herein is superior for a number of reasons, for example, for environmental and economic benefits because by placing the clean dry gas, such as methane, back in the ground, an energy resource is maintained for a later time. That resource can be used directly rather than having to rely on an additional costly and energetically inefficient separation processes to remove additional diluting gases. Foreign substances may not be needed; pure methane and other dry gaseous constituents may be returned to the shale formations from which it came.

[0055] Methane left in the ground, can now be tapped after the completion of future infrastructure (pipelines, liquefaction and reforming plants) that can handle it. In an embodiment, the process may result in overall fewer wells being drilled for the same amount of higher alkane gas. The process may conserve hydrocarbons, as the dry gas may be effectively banked for the future rather than used for some low value or even negative value purpose. When methane is used in the future, the process results in less carbon dioxide being produced, and avoids the need for separation and associated energy consumption.

[0056] For example, there are three economic benefits of this re-injection process. First, enhanced oil recovery techniques can increase the product yield up to double the product yield acquired per well. A second reason for using this process is to maintain a high-future-value resource in the form of methane and other dry gas constituents, which may be stored underground in pure form rather than diluting it with carbon dioxide as proposed by other groups. Third, oil producers may be alleviated from the economic burden of gaseous methane handling. Thus, the process allows wet gas to be used as a source of sweet light crude oil and chemical feedstocks.

[0057] Although the embodiments of the present teachings have been described in the accompanying embodiments and in the foregoing detailed description, it is to be understood that the present teachings are not to be limited to just the embodiments disclosed, but that the teachings described herein are capable of numerous rearrangements, modifications and substitutions.

We claim:

1. A method for increasing and maintaining the permeability of a fractured rock formation comprising:

forming at least one injection well at least partially within a fractured rock formation;

injecting and flowing a high pressure gas into the at least one injection well over a predetermined time scale;

permeating the fractured rock formation with the injected high pressure gas flow as it flows underground to at least one extraction well; and

collecting the high pressure gas in the at least one extraction well, and then extracting additional liquid and gas products from the at least one extraction well.

2. The method of claim **1**, wherein fractures in the fractured rock formation are produced by hydraulic fracturing using a working fluid, followed by injecting the high pressure gas over a predetermined time scale of at least one week, to maintain the permeability created via the hydraulic fracturing process.

3. The method of claim **2**, wherein the working fluid comprises at least one of the following: non-aqueous liquid, water, brine, polymers, carbon dioxide, methane, or a combination thereof.

4. The method of claim **2**, wherein the working fluid includes 95% or more of the following: methane, ethane, or a combination thereof.

5. The method of claim **1**, wherein cracks and fissures in the fractured rock formation are created exclusively from a high pressure working fluid.

6. The method of claim **1**, wherein the collected high pressure gas is separated to remove methane from liquid fractions obtained from extracted natural gas.

7. The method of claim **6**, further comprising:

compressing the methane to a higher pressure than the well bottom pressure of the at least one extraction well and then injecting or reinjecting the methane into a gas-bearing area of the fractured rock formation; and

blending the methane with natural gas stored inside a porous area of the fractured rock formation.

8. The method of claim **1**, wherein the pressure in the at least one extraction well is increased by injecting a non-condensable gas at a pressure higher than the pressure in the at least one extraction well, and creating an overburden pressure at the bottom of the at least one extraction well.

9. A method for increasing permeability of a rock formation containing natural gas comprising:

forming at least two boreholes in a rock formation, wherein a first borehole is externally pressurized with a working fluid to a level of at least 1,000 psi above the pressure of the rock formation and a second borehole is pressurized at a level below the pressure of the rock formation, such that the working fluid pressure differential is sufficient to cause fracturing in the rock formation between the first and second boreholes, and the working fluid to flow from one borehole to the other.

10. The method of claim **9**, wherein the external pressurization is decreased and residual natural gas is extracted from the first or second boreholes.

11. The method in claim **9**, further comprising:

flowing a working fluid from the first borehole to the second borehole, thereby causing residual natural gas to flow into the second borehole; and

extracting liquid constituents of the natural gas from the second borehole.

12. The method of claim **9**, wherein the working fluid is composed of a substantially non-aqueous liquid.

13. The method of claim **9**, wherein the working fluid comprises a gas chosen from the group including methane, ethane, alkane gases, carbon dioxide, carbon monoxide, nitrogen, natural gas, other reducing gases, inert gases, non-oxidizing gases, or a combination thereof.

14. The method of claim **9**, wherein the external pressurization is applied intermittently to maintain permeability between the first borehole and the second borehole.

15. The method of claim **9**, further comprising utilizing particles from the working fluid to maintain permeability in the rock formation.

16. A method for increasing the permeability of a rock formation containing natural gas comprising:

forming at least two boreholes, wherein a first borehole is externally pressurized with a working fluid, and surrounding boreholes are pressurized; and

increasing the porosity in an outward direction of a rock formation between the first borehole and the surrounding boreholes, wherein the first borehole is externally pressurized with a working fluid to a level of at least 1,000 psi above the rock pressure and the surrounding boreholes are either maintained or below the over burden pressure, such that the working fluid pressure differential is sufficient to cause fracturing in the rock formation between the surrounding boreholes and the working fluid flows from one borehole to another.

17. The method of claim **16**, wherein the pressurization is applied intermittently between the first borehole and the second borehole.

18. The method of claim **16**, comprising carrying particles in the working fluid to partially fill cracks in the rock formation and maintain permeability in a preferred direction in the rock formation.

19. The method of claim **16**, wherein the working fluid comprises a gas, such as methane, ethane, carbon dioxide, nitrogen, a higher alkane compound, or a combination thereof.

20. The process of claim **16**, wherein the working fluid includes antimicrobial materials.

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