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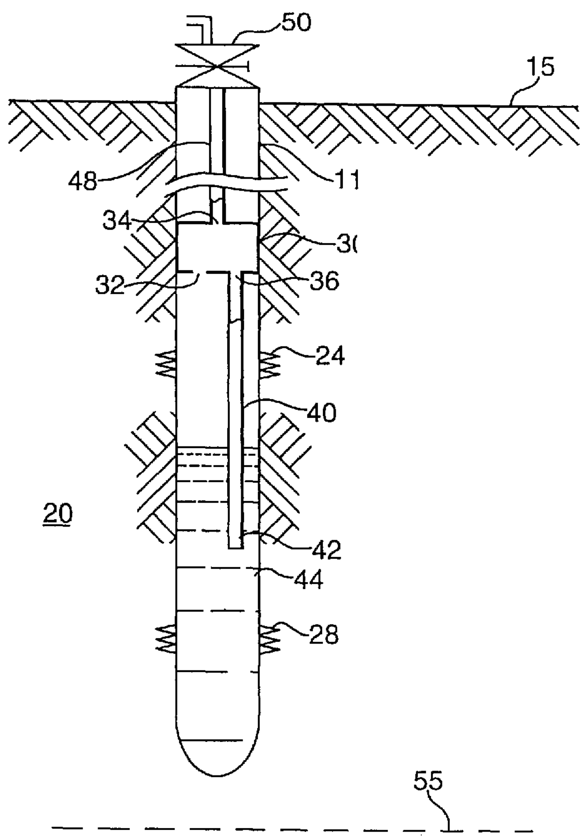
(54) Title: METHOD OF PRODUCING HYDROCARBON GAS



(57) Abstract: A method of producing gas from an underground formation, which is penetrated by a production well to surface, the method comprising allowing formation fluid comprising gas and liquid to flow into the production well at a production interval; allowing the formation fluid to separate into a gaseous component and a liquid component; producing the gaseous component through the production well to the surface; accumulating the liquid component in the production well so as to form a liquid column having, at a drainage interval of the production well, a pressure exceeding the pressure in the surrounding formation; and allowing liquid from the liquid column at the drainage interval to drain away into the surrounding formation, comprising treating the wall of the production well at the drainage interval and/or treating the formation surrounding the drainage interval so as to increase the flow rate of liquid into the surrounding formation.

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METHOD OF PRODUCING HYDROCARBON GAS

The present invention relates to a method and system of producing gas, in particular hydrocarbon gas, from an underground formation.

In known systems for producing gas, a production well is arranged to penetrate the gas-bearing formation. Reservoir fluid can be received in a production interval, e.g. through perforations in the well casing at a certain depth. The reservoir fluid often comprises liquids in addition to the gas, in particular water.

The liquids can be present in the formation fluid when it enters the production well, for example from a so-called high-permeability streak. Liquids can also be formed by condensation on the way to the surface in the event that the reservoir conditions (pressure, temperature) at the production interval depth are such that the formation fluid comprises vapour or liquid that is dissolved in the gas.

When the flow rate up the well is low enough, the liquid will separate from the formation fluid under the influence of gravity, will sink to the bottom of the well where it will accumulate to form a liquid column, generally a water column.

The formation of a water column is generally undesired, since the inflow of reservoir fluid will be hindered or even stopped when the water column fully or partially overlaps the production interval. A number of conventional methods are used in the art to deal with the formation of a water column is a gas well.

One method is to install production tubing in the well, so-called velocity strings, that serve to limit the effective cross-sectional area for the fluid produced to surface, thereby increasing the flow velocity sufficiently to prevent gas/liquid separation. Another method is to use foaming chemicals, which lower the surface tension of separated water so that it can be transported more easily to surface by the gas. Yet another known method is to pump water from the water column to surface, which is also referred to as plunger lift. In a further method a compressor is used to reduce the well head pressure.

US patent specification No. 5 913 363 discloses a method for downhole separation of water from gas received from a production zone in a gas well, using a downhole gas/water separator arranged above the production zone, wherein the separated water is directed via packers and a pressure sensitive valve to a disposal formation.

US patent specification No. 5 443 120 discloses a method for downhole separation of water from hydrocarbons by gravity, in a portion of an inclined wellbore that is isolated by packers, and wherein separated water is injected into a disposal formation which has a lower pressure than the producing formation.

US patent specification No. 5 366 011 discloses a gas well wherein a special casing/tubing arrangement is placed. The arrangement forms an annulus communicating with the producing formation and has a sliding sleeve to selectively allow fluid communication between the annulus and the tubing. Water can separate from the gas in the annulus and is allowed to flow into the tubing and from there into a non-productive interval.

US patent specification No. 6 336 504 discloses a method for downhole separation and injection of water, wherein the reservoir fluid contains at least some oil, water and optionally gas, and wherein a separator is arranged at a variable position in the well so as to produce water at a sufficient pressure for injection into a disposal formation.

The known methods are only applicable in special situations and all have disadvantages, in particular due to interference with the production of the gas, complexity and cost.

It is an object of the present invention to provide a new method for producing gas from an underground formation, wherein liquid separates from the formation fluid that is received at a production interval, and forms a liquid column in the production well.

It is a further object to provide a production well for carrying out the method of the present invention.

To this end, in accordance with the present invention there is provided a method of producing gas from an underground formation, which underground formation is penetrated by a production well extending to surface, which method comprises the steps of:

- allowing formation fluid comprising gas and liquid to flow from the underground formation into the production well at a production interval;
- allowing the formation fluid to separate into a gaseous component and into a liquid component;
- producing the gaseous component through the production well to the surface;
- accumulating the liquid component in the production well so as to form a liquid column having, at a drainage interval of the production well, a pressure exceeding the pressure in the surrounding formation; and
- allowing liquid from the liquid column at the drainage interval to drain away into the surrounding formation,

wherein the step of allowing liquid from the liquid column to drain away comprises treating the wall of the production well at the drainage interval and/or treating the formation surrounding the drainage interval so as to increase the flow rate of liquid into the surrounding formation.

There is further provided a production well for producing gas from an underground formation, which well extends downwardly from the earth's surface and is arranged to penetrate the underground formation, the production well comprising:

- a production interval for allowing formation fluid comprising gas and liquid to flow from the underground formation into the production well; and
- a drainage interval,

wherein the production well is arranged so that a liquid that separates during normal operation from the formation fluid is accumulated to form a liquid column covering at least partly the drainage interval, and wherein the drainage interval is arranged so as to allow liquid from the liquid column to drain away into the surrounding formation, by treating the wall of the production well at the drainage interval and/or treating the formation surrounding the drainage interval.

The invention is based on the insight gained by Applicant, that the liquid can be drained away into the formation by virtue of its own weight, i.e. due to the hydrostatic pressure formed in the liquid column, if there is sufficient fluid communication between the drainage interval and the surrounding formation. This is advantageous for a number of reasons. A first advantage is, that by applying the method a limit can be put on the height that the liquid column achieves during normal operation. Therefore, the barrier to inflowing formation fluid that is formed by the liquid column is also limited. A further advantage is, that water which is contained in the reservoir fluid does not need to be produced to the surface, and can simply be disposed underground in a variety of practical situations without the need for special reinjection facilities such as a separate reinjection well and pumps.

It shall be clear that the drainage interval can be arranged separately underneath the production interval. In the event that the well comprises a long interval that is in direct fluid communication with the surrounding gas bearing formation, and wherein during normal operation a liquid column is formed in the well that partially overlaps this interval, the upper part of the interval represents a production interval and the lower part a drainage interval, the boundaries being defined by the amount of overlap.

Allowing the liquid from the liquid column to drain away suitably comprises treating of the wall of the well and/or treating the formation surrounding the drainage interval so as to make it easier for liquid to flow into the surrounding formation. Treatment of the wellbore wall can be particularly advantageous in the case when the wellbore is not cased.

Suitably, perforations are arranged in the wall of the production well at the drainage interval, in particular when the well is provided with casing.

The invention will now be explained by way of example in more detail, with reference to the Figures wherein

Figure 1 shows schematically a pressure distribution in a well with a liquid column and a gas column on top;

Figure 2 shows calculated example curves of liquid drainage rates $Q_{l,d}$ as a function of the permeability-thickness product $(kh)_{inj}$, for three liquid column heights;

Figure 3 shows a calculated example curve of the liquid drainage time constant τ as a function of the permeability-thickness product $(kh)_{inj}$;

Figure 4 shows calculated example curves of the height H as a function of the permeability-thickness product $(kh)_{inj}$, for three liquid entry rates;

Figure 5 shows schematically a first embodiment of the invention; and

Figure 6 shows schematically a second embodiment of the invention.

Reference is made to Figure 1. The Figure shows schematically the distribution of the pressure p (units: Pa) along the depth d (units: m) of a vertical well which has a liquid column at the bottom and a gas column on top thereof, in a static situation such as during shut-in of a gas well. The pressure at the surface (d=0) is denoted with p_0. The well is filled with gas between the surface and the depth of the top of the liquid column, d_l. The pressure p in this gas filled part 1 increases linearly with depth d, $p(d) = p_0 + \rho_g g d$, wherein ρ_g is the density of the gas (kg/m^3), and g is the standard gravity of the earth.

In the liquid column (reference numeral 3 in the Figure), the hydrostatic pressure p increases with depth proportional with the density of the liquid, ρ_l (kg/m^3), $p(d) = p_0 + \rho_g g d_t + \rho_l g(d - d_l)$. When at a certain depth the well is in fluid communication with the surrounding formation, and when the pressure in the formation is lower there, liquid will drain into the formation.

In a simple model for shut-in of a gas well, the pressure distribution as a function of depth in the gas bearing formation surrounding the well is equal to the pressure distribution of an entirely gas-filled well when the well is closed at the top, i.e. corresponds to the pressure distribution as formed by parts 1 and 5 of the pressure curve in Figure 1. In this case, when the well is provided with drainage perforations at a depth $d_p > d_l$, the driving force for the drainage of a liquid column is the pressure difference $\Delta p = (\rho_l - \rho_g)g(d_p - d_l)$.

In this case the drainage rate $Q_{l,d}$ (m^3/s) with which the liquid column drains away can be estimated as

$$Q_{l,d} = \frac{2\pi(kh)_{inj}}{\mu_l\{\ln(\frac{r_e}{r_w}) + S\}}.\Delta p, \qquad (1)$$

wherein

$(kh)_{inj}$ denotes the permeability-thickness product of the formation at the drainage interval (m^3);

μ_l denotes the viscosity of the liquid (Pa.s);

r_e is the drainage radius of the well (m);

r_w is the well bore radius (m);

S is the skin factor (numeral);

and Δp has been defined before.

An expression for the characteristic time for drainage of a liquid column can be derived under the assumption, that the liquid volume dV that drains away in a differential time unit dt is proportional to the height H of the liquid column above the drainage interval, $H=(d_p - d_l)$. The proportionality constant is obtained from equation (1). Integration of a differential equation thus obtained yields a single exponential decay of the height of the liquid column with time, wherein the time constant τ (s) is given by

$$\tau = \frac{r_w^2\mu_l\{\ln(\frac{r_e}{r_w}) + S\}}{2(kh)_{inj}\Delta\rho g}, \qquad (2)$$

wherein $\Delta\rho = (\rho_l - \rho_g)$, and wherein all other symbols have the same meaning as defined before.

Reference is now made to Figure 2, which shows liquid drainage rates $Q_{l,d}$ (in m^3/day) as a function of the permeability-thickness product $(kh)_{inj}$ (in millidarcy.meter). Curves are shown for three different heights H of the top of the liquid column above the top of the drainage perforations, a) H= 5m; b) H= 25m; c) H= 100m. The curves have been calculated on the basis of equation (1), using the following parameters of Table 1 which have been selected for a typical gas well.

Table 1.

Quantity	Value
r_e	850 m
r_w	0.1 m
(mechanical) well skin S	+5
Liquid (water) viscosity μ_l	0.4 mPa.s
Liquid (water) density ρ_l	1000 kg/m^3
Gas density ρ_g	75 kg/m^3

The rate at which liquid (water) enters the well $Q_{l,e}$ during gas production is typically in the order of 1...4 m^3/day, and is also indicated in Figure 2. The Figure indicates that when the well is shut in, the rate with which the water drains away is in the same order of magnitude or larger than the water entry rate.

Figure 3 shows the time constant τ (in days) of equation 2 as a function of the permeability-thickness product $(kh)_{inj}$ (in millidarcy.meter), calculated using the parameter values of Table 1.

Equations 1 and 2 have been derived for a gas well that is shut-in, i.e. closed at the surface so that no gas is produced. When the well is shut-in for about 5 times the time constant τ, the liquid column above the drainage perforations will have disappeared.

Also when the well is not shut-in, water will drain away while reservoir fluid is received in the well in a production interval above the drainage interval. In a steady state situation, the liquid entry rate $Q_{l,e}$ equals the liquid drainage rate $Q_{l,d}$. An estimate for the liquid column height H (m) in the steady state can be obtained by rearranging equation (1) and by substituting $Q_{l,d}$ for $Q_{l,e}$, giving

$$H = \frac{Q_{l,e} \cdot \mu_l \cdot \{\ln(\frac{r_e}{r_w}) + S\}}{2\pi(kh)_{inj}\Delta\rho g}, \quad (3)$$

wherein all symbols have the meaning as defined before.

Figure 4 shows the height H calculated by using equation (3) using the parameters in Table 1 for three liquid entry rates, a) $Q_{l,e} = 1\ m^3/day$; b) $Q_{l,e} = 2\ m^3/day$; c) $Q_{l,e} = 4\ m^3/day$.

It will be clear that, if the liquid entry rate $Q_{l,e}$ is larger than a critical liquid entry rate $Q_{l,e;crit}$, the height of the liquid column would become larger than the well could accommodate for normal operation. In that case the production of the gaseous component to the surface can be interrupted at intervals for a time period long enough to allow sufficient liquid to drain away into the formation, e.g. 5 times the time constant τ. During these shut-ins the liquid column height is reduced to below a predetermined height, whereafter production can be continued.

When the liquid entry rate is smaller than the critical liquid entry rate, the gaseous component can be produced continuously to the surface, while liquid is allowed to drain away simultaneously with producing the gaseous component.

The value of the critical liquid entry rate $Q_{l,e;crit}$ depends on a number of factors such as the the liquid/gas ratio of the inflowing reservoir fluid, the well geometry, the arrangement of perforations, the drainage characteristics, and the reservoir pressure and temperature. It can in principle be determined using a simulation tool.

Depending on the practical situation, there are a number of ways for allowing the liquid to drain away at the drainage interval.

When the wellbore is left uncased at the drainage interval, draining may occur naturally once a liquid column of sufficient height is formed.

Another suitable way is to arrange perforations in the wall of the production well, in particular when the well is provided with casing.

If in a given situation the liquid entry rate is larger than the critical liquid entry rate, the drainage rate of liquid into the formation can be increased by treating the wall of the production well at the drainage interval and/or treating the formation surrounding the drainage interval. This treatment makes it easier for liquid to flow into the surrounding formation. Treatment of the wellbore wall can be particularly advantageous in the case when the wellbore is not cased. Such a treatment normally reaches only a limited distance into the formation.

One suitable treatment of the wellbore wall is a treatment using chemicals. For example, an acid such as hydrochloric acid can be used in order to remove mud and fines that have precipitated at the wellbore wall, thereby lowering the barrier ("skin") for liquid to flow into the formation. The acid can be pumped downhole and will mix with the water column. Acid does not remain active for long, normally shorter than 24 hours.

In a suitable treatment of the formation surrounding the drainage interval, pressure pulses are applied to the liquid column so as to generate micro fractures deeper in the formation surrounding the drainage interval. Pressure pulses can be provided using means known in the art via hydraulic pulses, also referred to as acoustic pulses.

Chemical and pressure treatment can also be applied in combination, so as speed up the chemical reaction, and also in order to edge microfractures that are formed in the formation.

When the flow rate Q_g (m^3/s) of the gas up the production well is low enough, and consequently the flow velocity in the well, the fluid will separate so that the liquid will sink to the bottom of the well where it will accumulate to form a liquid column.

At higher gas flow rates liquid separation does not occur naturally. An estimate for the critical gas flow $Q_{g,crit}$, below which separation occurs naturally under the influence of gravity, can be obtained by the equation

$$Q_{g,crit} = \frac{\pi D^2 c}{4} \cdot \left[\frac{(\rho_l - \rho_g) g \sigma}{C_D \rho_g^2} \right]^{1/4}, \qquad (4)$$

which is also known in the art as the Turner criterion. The symbols used in the equation have the following meaning:

D = diameter of the well (m);

c = a numerical constant, suitably in the order of 2;

ρ_l = density of the liquid (kg/m^3);

ρ_g = density of the gas (kg/m^3);

σ = surface tension (kg/s^2);

C_D = drag coefficient (numerical).

A typical critical gas flow rate corresponds to a gas velocity of approximately 5-6 m/s.

When the gas flow rate is above the critical gas flow rate, the flow energy of the gas is sufficiently high to carry the liquid to surface, which is also called the mist flow regime. In this event, the method of the present invention can advantageously be used by arranging a gas/liquid separator, either in the well or on surface.

This separator is arranged so as to receive formation fluid through an inlet, and has outlets for at least a gaseous stream and a liquid stream. The liquid stream is then used to form the liquid column in the well. Suitable separators for this purpose are known in the art, e.g. a cyclone separator, a plate pack separator, a curved guiding vane separator, or a mist mat.

When the formation fluid contains vapour or fluid dissolved in the gas that condenses only when the fluid has risen to a certain depth in the well, the separator is preferably arranged above this depth.

Reference is now made to Figure 5, showing schematically a first embodiment of the invention. A production well 11 extends vertically downwardly from the surface 15 and penetrates a gas-bearing formation 20. The well is provided with casing (not shown), and perforations are arranged at a production interval 24 and a drainage interval 28 below the production interval. In the well, above the drainage interval, there is a separator 30 having an inlet for reservoir fluid 32, an outlet for gas 34, and an outlet for liquid 36. A conduit 40 is arranged from the outlet 36 to a position 42 below the production interval, within or above the region wherein during normal operation the liquid column 44 is formed. The conduit 40 serves to prevent the separated liquid from being re-entrained by the gas. Production tubing 48 provides fluid communication for the gas between the outlet 34 and the wellhead 50.

During normal operation, reservoir fluid comprising gas and water flows into the well 11 at the production interval 24. The reservoir fluid rises in the well and enters the separator 30 through the inlet 32. The separator separates the reservoir fluid into a component consisting mainly of gas, and into a liquid component.

The gas component is conducted to surface via production tubing 48. The liquid is guided to a position below the production interval, where a liquid column 44 is formed.

The height of the liquid column above the drainage interval perforations 28 exerts a hydrostatic pressure larger than the pressure in the formation 20 at the drainage interval. Thereby the liquid from the water column 44 can drain into the formation through the perforations at the drainage interval. When the liquid entry rate $Q_{l,e}$ is smaller than the critical liquid entry rate $Q_{l,e;crit}$, the gaseous component can be produced continuously to the surface, while liquid is allowed to drain away simultaneously. If needed, the drainage interval or the formation surrounding the drainage interval can be treated by one of the methods described hereinbefore, so as to allow continuous operation, in particular so that the flow rate of inflowing water at the production interval 24 substantially equals the rate of water drained into the formation at the drainage interval 28. Alternatively, if the liquid entry rate is too large, production of gas can be stopped by closing the production tubing 48 at the wellhead 50, so as to allow more time for the liquid to drain away.

When the water has drained into the formation 20, it will preferably sink in the formation to the level of the water gas contact 55, so that the drained water is not produced back. The time scale of this process is determined by the vertical permeability of the formation.

It shall be clear that the separator 30 does not need to be present if the rate of inflowing gas is below the critical gas flow rate.

Reference is made to Figure 6, which shows schematically another embodiment of the invention. Like numerals as in Figure 5 are used to refer to the same objects. The well 60 is cased only at the top and uncased at and below the region 62.

During normal operation of this well, formation fluid comprising gas and water enters the well 60 in the uncased part and rises. The total gas flow rate is low enough so as to allow separation of water droplets 63 which sink to the bottom of the well where they accumulate to form a liquid column 44. The liquid column, during normal operation, extends to a level which defines the lower end of region 62.

In region 62, reservoir fluid can enter the well without hindrance.

In the region 64, the pressure in the well due to the hydrostatic pressure of the water column is still smaller than the pressure in the formation, so that in region 64 also formation fluid can enter the well as indicated by the arrows, be it somewhat hindered as compared to region 62. Regions 62 and 64 form the production interval.

In the area 66 the hydrostatic pressure in the liquid column is such that the well pressure about equals the pressure in the surrounding formation, so that virtually no fluid is exchanged between well and formation there.

In the region 68, the hydrostatic pressure is large enough so that the water can drain into the formation. Region 68 forms the drainage interval.

Again, the wellbore wall and/or surrounding formation can be treated to as to allow sufficient fluid to be drained away for continuous operation.

It shall be clear that four basic regimes for operation can be distinguished in the operation of the method and system of the present invention (using the symbols as defined before):

1. $Q_g < Q_{g,crit}$ and $Q_{l,e} < Q_{l,e;crit}$, so no gas/liquid separator is needed, and continuous operation is possible;
2. $Q_g < Q_{g,crit}$ and $Q_{l,e} > Q_{l,e;crit}$, so no gas/liquid separator is needed, but discontinuous operation is required;
3. $Q_g > Q_{g,crit}$ and $Q_{l,e} < Q_{l,e;crit}$, so a gas/liquid separator is needed, and continuous operation is possible;
4. $Q_g > Q_{g,crit}$ and $Q_{l,e} > Q_{l,e;crit}$, so a gas/liquid separator is needed as well as discontinuous operation.

Instead of discontinuous operation, further treatment of the wellbore and/or formation can be performed so as to make it easier for liquid to drain into the formation, thereby increasing $Q_{l,e;crit}$.

C L A I M S

1. A method of producing gas from an underground formation, which underground formation is penetrated by a production well extending to surface, which method comprises the steps of:
- allowing formation fluid comprising gas and liquid to flow from the underground formation into the production well at a production interval;
- allowing the formation fluid to separate into a gaseous component and into a liquid component;
- producing the gaseous component through the production well to the surface;
- accumulating the liquid component in the production well so as to form a liquid column having, at a drainage interval of the production well, a pressure exceeding the pressure in the surrounding formation; and
- allowing liquid from the liquid column at the drainage interval to drain away into the surrounding formation,

wherein the step of allowing liquid from the liquid column to drain away comprises treating the wall of the production well at the drainage interval and/or treating the formation surrounding the drainage interval so as to increase the flow rate of liquid into the surrounding formation.

2. Method according to claim 1, wherein the step of allowing liquid to drain away comprises arranging perforations in the wall of the production well at the drainage interval.

3. The method according to claim 1 or 2, wherein the wall of the production well is treated by adding a chemically active agent to the liquid.

4. The method according to claim 3, wherein the chemically active agent is an acid.

5. The method according to any one of claims 1-4, wherein the surrounding formation is treated by generating fractures therein.

6. The method according to any one of claims 1-5, wherein pressure pulses are applied to the liquid column.

7. Method according to any one of the previous claims, wherein the step of allowing the formation fluid to separate comprises controlling the flow rate of the produced gaseous component in the production well to remain below a critical gas flow rate, such that formation fluid can separate in the production well in the absence of a dedicated separator.

8. Method according to any one of claims 1-6, wherein the step of allowing the formation fluid to separate comprises admitting the formation fluid to the inlet of a gas/liquid separator, which has outlets for the gaseous component and for the liquid component.

9. Method according to claim 8, wherein the liquid received at the outlet for liquid of the separator is guided through a conduit to a position below the production interval.

10. The method according to claim 8 or 9, wherein the gas/liquid separator is arranged in the production well.

11. The method according to claim 10, wherein the formation fluid comprises liquid vapour or liquid dissolved in the gas, and wherein the gas/liquid separator in the production well is arranged above the depth, at which during normal operation liquid condenses from the formation fluid.

12. Method according to claim 8 or 9, wherein the separator is arranged at the surface.

13. Method according to any one of the previous claims, wherein, during normal operation, the gaseous component

is produced continuously to the surface, and wherein liquid from the liquid column is allowed to drain away simultaneously with producing the gaseous component.

14. Method according to any one of claims 1-12, wherein, during normal operation, the production of the gaseous component is at intervals interrupted for a period long enough to allow sufficient liquid from the liquid column to drain away into the formation, so that the liquid column height is reduced to below a predetermined height.

15. Method according to any one of the previous claims, wherein the gaseous component mainly consists of hydrocarbon gas, and wherein the liquid mainly consists of water.

16. A production well for producing gas from an underground formation, which well extends downwardly from the earth's surface and is arranged to penetrate the underground formation, the production well comprising:

- a production interval for allowing formation fluid comprising gas and liquid to flow from the underground formation into the production well; and
- a drainage interval,

wherein the production well is arranged so that a liquid that separates during normal operation from the formation fluid is accumulated to form a liquid column covering at least partly the drainage interval, and wherein the drainage interval is arranged so as to allow liquid from the liquid column to drain away into the surrounding formation, by treating the wall of the production well at the drainage interval and/or treating the formation surrounding the drainage interval.

17. A production well according to claim 16, further comprising a gas/liquid separator having an inlet for formation fluid, an outlets for a separated gaseous component and an outlet for a separated liquid component.

Fig.5.

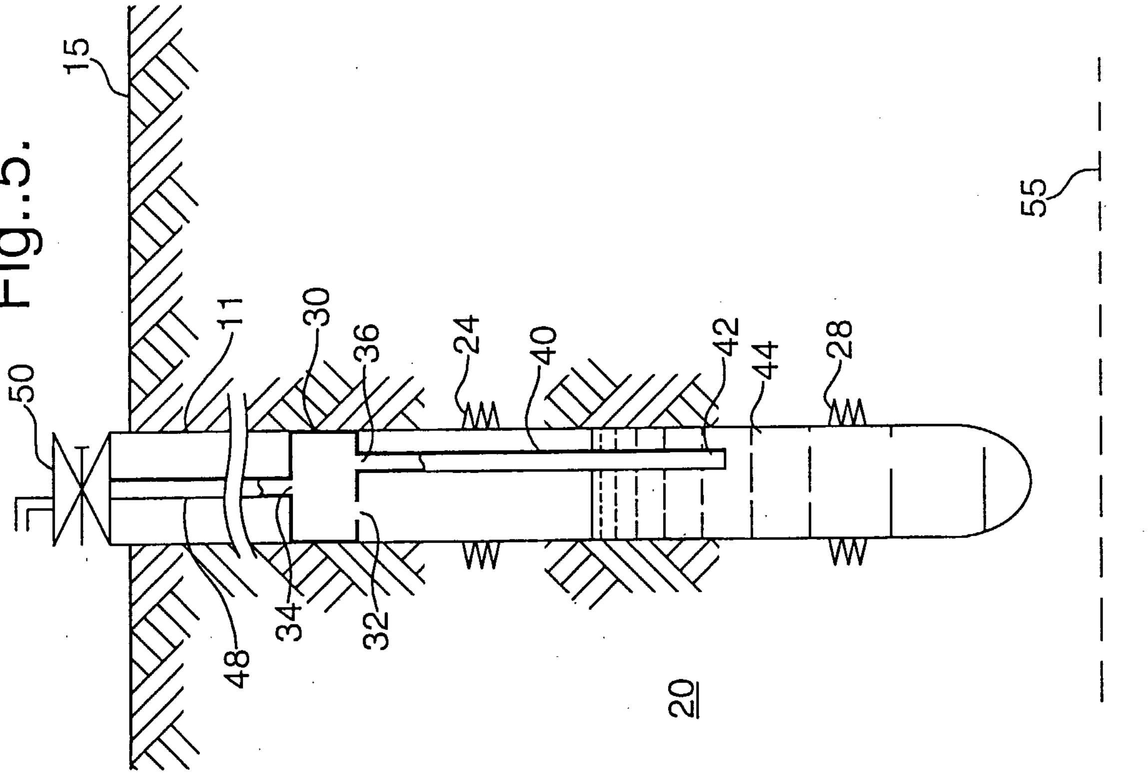


Fig.1.

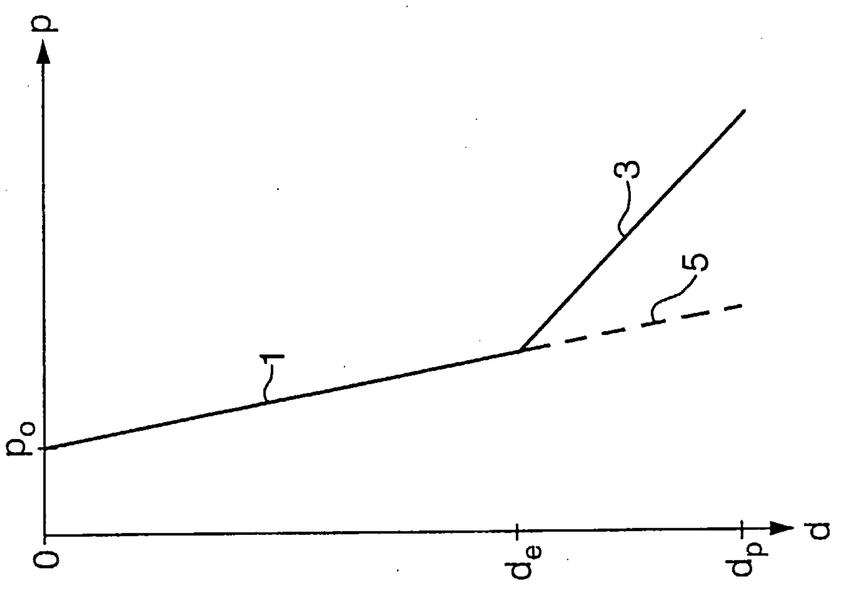
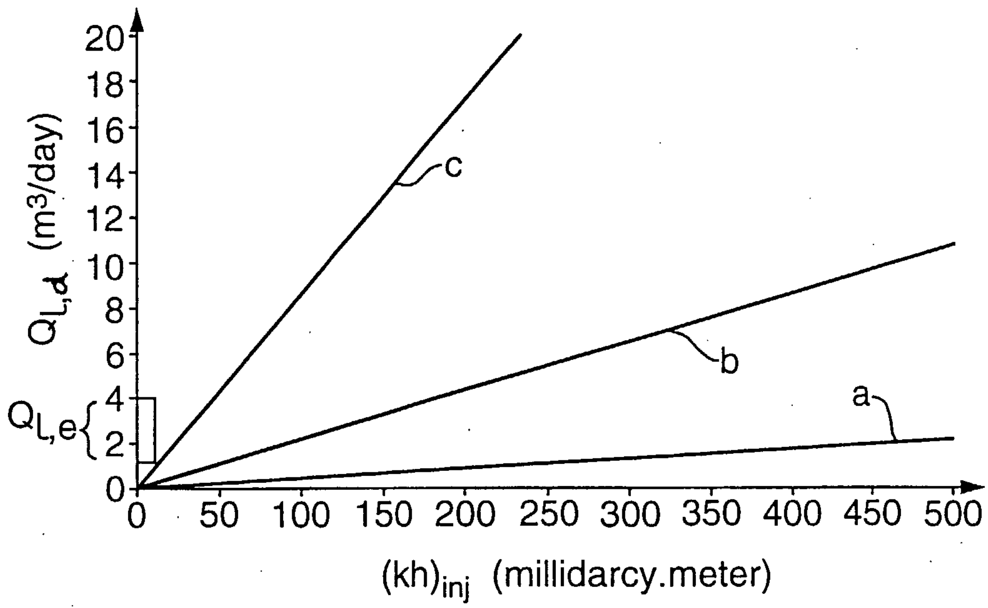


Fig.2.


20
18
16
14
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8
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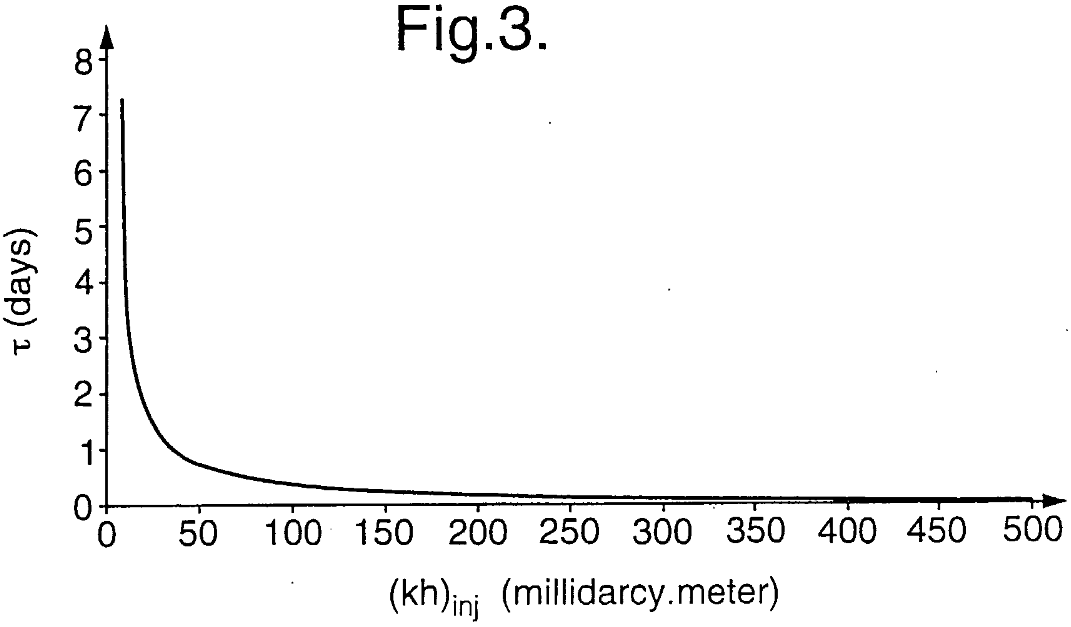
0
$Q_{L,d}$ (m³/day)
$Q_{L,e}$
c
b
a
0 50 100 150 200 250 300 350 400 450 500
$(kh)_{inj}$ (millidarcy.meter)

Fig.3.


8
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τ (days)
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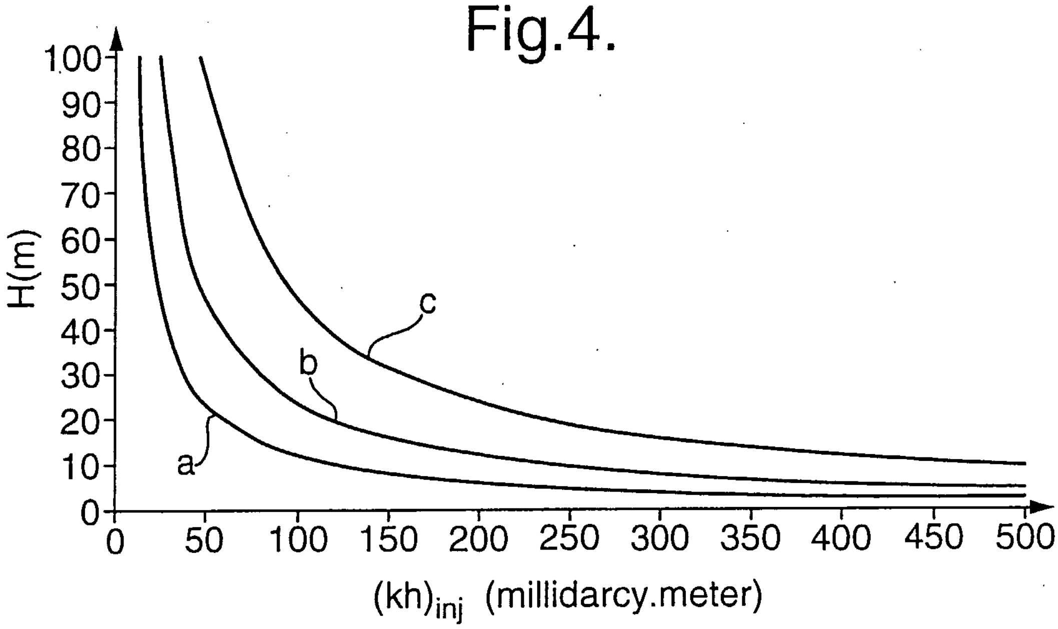
$(kh)_{inj}$ (millidarcy.meter)

Fig.4.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30
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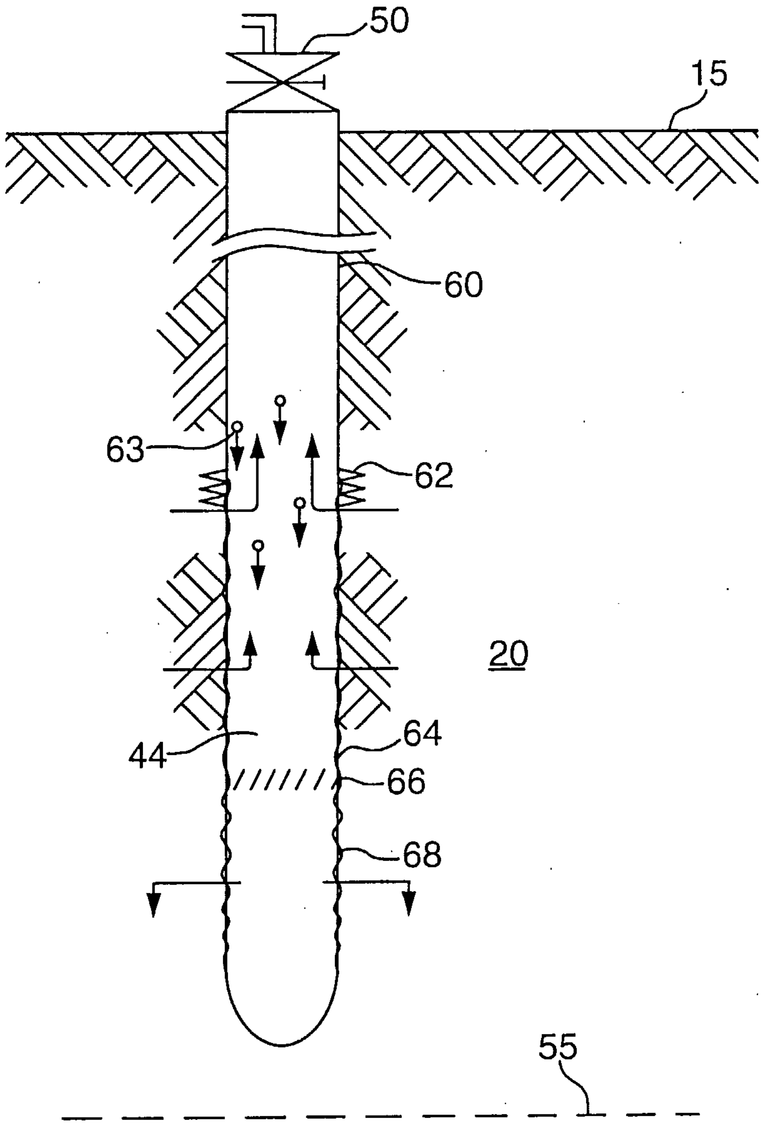
10
0
H(m)
a
b
c
0
50
100
150
200
250
300
350
400
450
500
(kh)inj (millidarcy.meter)

Fig.6.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/04360

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 913 363 A (PAPLINSKI) 22 June 1999 (1999-06-22) column 3, line 24 - line 35	1,2,9, 11,14, 16-18
X	US 5 443 120 A (HOWELL) 22 August 1995 (1995-08-22) column 5, line 1 - line 10	1,2, 9-11,14, 16-18
X	US 5 366 011 A (JENNINGS) 22 November 1994 (1994-11-22) column 3, line 5 - line 13	1,13,17
X	WO 01 65064 A (PAN-CANADIAN PETROLEUM LTD) 7 September 2001 (2001-09-07) page 3, line 29 - line 31 page 5, line 12 - line 15	1,17

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 August 2003	20/08/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Rampelmann, K

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 131 161 A (LACQUEMENT) 26 December 1978 (1978-12-26) column 2, line 6 - line 43 ---	1,17
X	US 6 336 504 B1 (ALHANATI ET AL.) 8 January 2002 (2002-01-08) abstract ---	1,17
A	US 3 363 692 A (BISHOP) 16 January 1968 (1968-01-16) column 4, line 23 - line 52 ---	1
A	US 5 836 393 A (JOHNSON) 17 November 1998 (1998-11-17) column 1, line 47 - line 53 ---	7
A	GB 2 326 895 A (SCHLUMBERGER LTD) 6 January 1999 (1999-01-06) page 11, line 20 -page 12, line 25 -----	8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 03/04360

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5913363	A	22-06-1999	CA	2196959	A1	06-08-1998
US 5443120	A	22-08-1995	CA	2155704	A1	26-02-1996
			GB	2292574	A ,B	28-02-1996
			NO	953282	A	26-02-1996
US 5366011	A	22-11-1994	NONE			
WO 0165064	A	07-09-2001	US	6336504	B1	08-01-2002
			AU	3904301	A	12-09-2001
			WO	0165064	A1	07-09-2001
			CA	2339478	A1	03-09-2001
			EP	1266122	A1	18-12-2002
US 4131161	A	26-12-1978	NONE			
US 6336504	B1	08-01-2002	AU	3904301	A	12-09-2001
			WO	0165064	A1	07-09-2001
			CA	2339478	A1	03-09-2001
			EP	1266122	A1	18-12-2002
US 3363692	A	16-01-1968	NONE			
US 5836393	A	17-11-1998	NONE			
GB 2326895	A	06-01-1999	NONE			