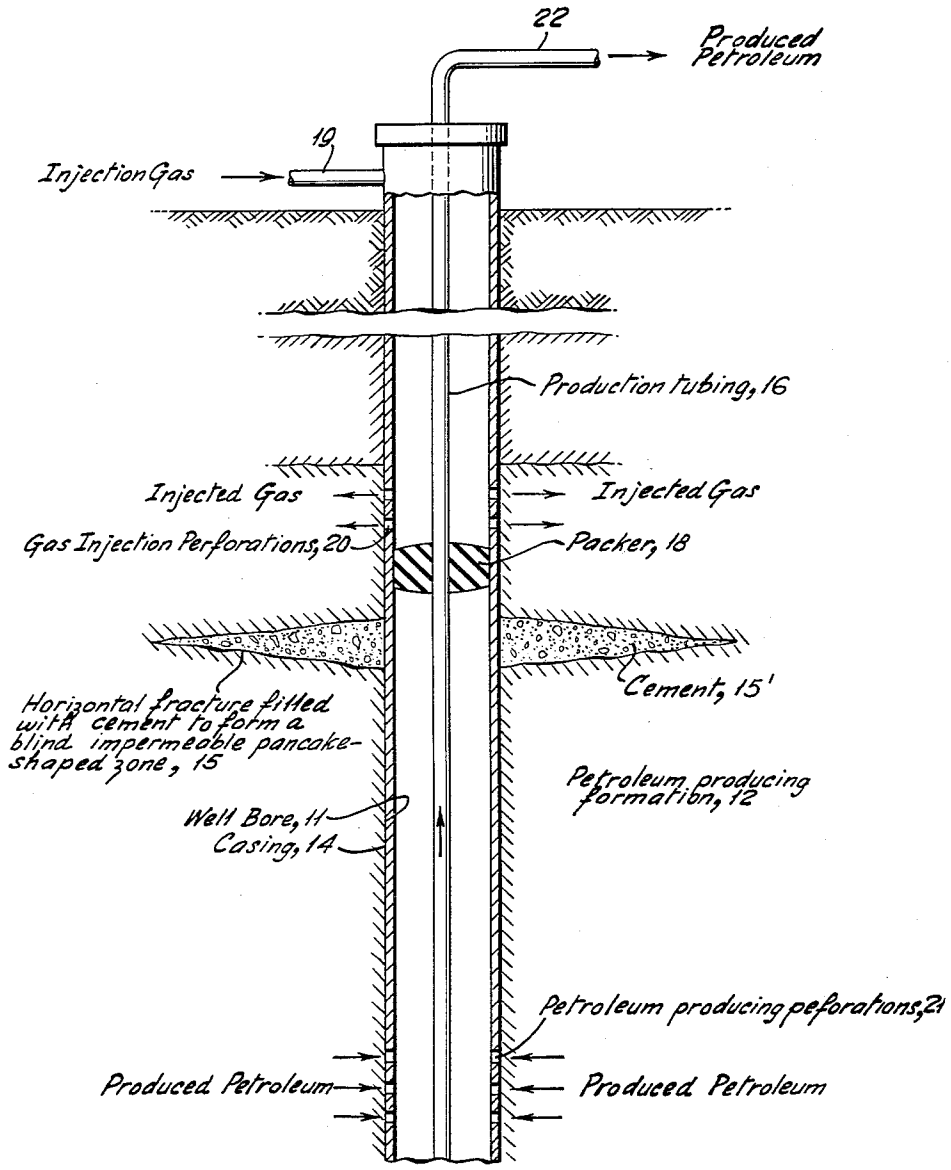
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PRODUCING PETROLEUM FROM A SUBSURFACE FORMATION

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PRODUCING PETROLEUM FROM A SUBSURFACE FORMATION

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This invention relates to the recovery and production of petroleum from a subsurface petroleum-producing formation. In accordance with one embodiment this invention relates to the recovery and production of petroleum from a subsurface petroleum-containing formation employing an operation wherein a well bore is employed both as a gas injection well and as a petroleum production well.

One of the most efficient methods of displacing petroleum from a subsurface petroleum-producing formation, particularly a formation having considerable structural relief, is the injection of gas high in the formation, near the top or crest, and producing oil from near the bottom of the formation or lower portion thereof. By operating in this fashion advantage is taken of the natural segregating effect of gravity. There are many formations, however, which possess relatively little structural relief or dip. In the production of petroleum from such formations by injection of gas into the upper portion thereof a multitude of injection wells is required so that the injected gas is forced evenly downwardly, in a blanket-like manner, into the petroleum-producing formation while producing petroleum from the lower portions thereof so that during the gas injection and petroleum production operations advantage may be taken of the segregating effect of gravity. As indicated, however, this method involves the employment of very many wells and, consequently, in most instances is economically prohibitive.

It is an object of this invention to provide an improved method for the recovery and production of petroleum from a subsurface petroleum-producing formation.

Another object of this invention is to provide an improved method of recovering and producing petroleum from a subsurface petroleum-producing formation involving operations wherein the same well bore penetrating the petroleum-producing formation is employed as a gas injection well and as a petroleum production well.

Another object of this invention is to provide a method wherein a petroleum-producing formation can be produced by the injection of gas into the upper portion thereof while petroleum is being produced from the lower portion thereof, and wherein premature fingering or short circuiting of the injected gas from the upper portion of the formation into the lower portion of the formation in the vicinity of the well bore during the petroleum production operation is inhibited and/or obviated.

Yet another object of this invention is to provide a method for the production of petroleum from subsurface petroleum-producing formations having relatively little structural relief or dip.

Still another object of this invention is to provide a method of producing petroleum from subsurface petroleum-producing formations involving operations wherein advantage is taken of the segregating effect of gravity.

How these and other objects of this invention are accomplished will become apparent in the light of the accompanying disclosure and drawing wherein there is schematically illustrated a petroleum production operation carried out in accordance with the practice of this invention. In at least one embodiment of the practice of this invention at least one of the foregoing objects will be achieved.

In accordance with this invention an improved method of recovering and producing petroleum from a subsurface petroleum-containing formation is accomplished by sealing off an upper portion of the petroleum-producing formation to create a substantially fluid or gas impermeable zone therein in the vicinity of the well bore, followed by the injection of gas into the upper portion of the formation at a location above the aforesaid gas impermeable zone and producing petroleum from the lower portion of the formation beneath the aforesaid fluid or gas impermeable zone within the upper portion of the formation.

Various methods may be employed in the practice of this invention for the creation of a gas impermeable zone in the upper portion of the formation prior to the injection of gas into the formation above said zone. One method particularly suitable for use in the practice of this invention involves fracturing the petroleum-producing formation in the upper portion thereof to create a substantially horizontal fracture, such as a fracture extending substantially horizontally, radially outwardly from the well bore. The resulting fracture is then treated in such a manner as to render the fracture and that portion of the formation immediately encompassing the fracture substantially gas impermeable. Suitable methods for rendering a permeable formation or fracture substantially gas impermeable include cementing wherein cement is forced into the fracture and permitted to set therein with the resultant creation of a fluid impermeable zone and fracture. Desirably, a fluid cement may be employed as the fracturing fluid with the result that upon completion of the fracturing operation the fracture is occupied by the cement which subsequently sets up therein to an impermeable mass. Another method of creating a substantially fluid or gas impermeable zone within a subsurface petroleum-producing formation, without the necessity of creating a fracture therein, involves the injection into the formation of a fluid or liquid cement or liquid plugging agent which permeates the formation in the zone of injection and eventually sets up therein, per se, or by the subsequent addition of a treating agent. Other methods of creating a substantially fluid impermeable zone or barrier within a petroleum-producing formation are known.

Any gas may be suitably employed as a pressure gas in the practice of this invention. Desirably, however, the gas injected into the petroleum-producing formation, above the fluid or gas impermeable zone created therein, is natural gas, preferably gas recovered from the formation undergoing treatment. Natural gas comprises a major amount of methane and minor amounts of ethane, propane and butane. Accordingly, any of the aforesaid normally gaseous hydrocarbons, alone or in any suitable admixture, may be suitably employed in the practice of this invention as the pressuring gas. Other suitable pressuring gases include flue gas, carbon dioxide, carbon monoxide, air, nitrogen, etc.

The substantially fluid or gas impermeable zone created within the upper portion of the petroleum-producing formation extends substantially horizontally, outwardly, radially from the well bore for a considerable distance, such as a distance in the range 10–200 feet, more or less. Preferably the outer periphery of the fluid impermeable zone created within the petroleum-producing formation is sufficiently distant from the well bore and the lower portion of the formation wherefrom petroleum is produced so that the buoyancy effect, exerted upon the gas injected into the upper portion of the formation, due to the density difference between the gas and the denser liquid petroleum therein, is at least as great as or greater than the pressure differential, exerted upon an increment of gas at the outer periphery of the zone, resulting from the flow of petroleum into the well bore in the lower portion of the formation during the petroleum-producing operation. In other words, the injected

gas which reaches the outer periphery of the zone will not be drawn downward directly but will occupy the upper portion of the formation and descend in blanket-like fashion to displace petroleum into the lower portion of the formation.

Referring now in detail to the accompanying drawing which schematically illustrates an embodiment of the practice of this invention wherein natural gas is injected into the upper portion of the formation while petroleum is produced from the lower portion of the formation, the gas being injected into and the petroleum being produced via the same well bore, a well bore **11** is shown penetrating petroleum-producing formation **12**. The well bore is provided with casing **14**. In accordance with this invention, as illustrated in the drawing, a fracture **15** extending substantially horizontally and radially outwardly from well bore **11** is created within the petroleum-producing formation **12** in the upper portion thereof and filled with cement **15'** permitted to set therein with the resultant creation of a substantially fluid impermeable pancake-shaped zone surrounding the well bore **11**.

There is provided within the well bore **11**, substantially concentric with respect to casing **14** therein, production tubing **16**. In the annular space between production tubing **16** and casing **14**, above the cement filled fracture **15**, there is positioned a packer **18** made of suitable expansible material. The packer **18** serves to make a fluid tight seal between casing **14** and production tubing **16**. Following the setting of packer **18** natural gas, methane, supplied from a suitable source at the surface via conduit **19** is injected into the annular space between casing **14** and tubing **16**. The thus-injected gas flows down the annulus between casing **14** and tubing **16** and outwardly into the upper portion of petroleum-producing formation **12** via perforations **20** at a location above cement filled fracture **15**. As the gas is injected into the upper portion of the formation above the fluid impermeable cement filled fracture **15**, or subsequently thereto, continuously or intermittently petroleum is produced from the lower portion of formation **12** via perforations **21** provided in the lower end of casing **14**. The resulting produced petroleum moves upwardly within production tubing **16** and is produced at the surface via conduit **22**.

In accordance with the foregoing operations injected gas enters the petroleum-producing formation **12** via perforations **20** and migrates outwardly into the formation **12** occupying the upper portion thereof. Since the outer periphery of the cement filled fracture **15** is sufficiently removed or remote from the production perforations **21**, the downwardly directed pressure gradients surrounding perforations **21** within the lower portion of the formation **12** are insufficient to cause short circuiting or by-passing of the injected gas downwardly along the well bore **11** into perforations **21**. As a result the injected gas tends to follow the contour lines within the producing formation **12** and migrates in a blanket-like manner downwardly within formation **12** displacing the hydrocarbons. It is to be noted also that the substantially fluid or gas impermeable zone within the upper portion of the formation **12**, created by the cement filled fracture **15** therein, positively prevents any short circuiting or by-passing of the injected gas downwardly along well bore **11** in the direction of production perforations **21**.

One or more of the aforesaid operations may be carried out consecutively with respect to the same well bore. For example, when it is found that the injected gas is entering production perforations **21** in excessive amounts, the formation may be again treated or fractured, and a fluid-impermeable zone created therein in the zone of the formation adjacent perforations **21**, but below these perforations. If these perforations **21** are not needed to achieve the desired gas injection capacity they should be sealed off, and gas injection maintained through perforations **20** into formation **12**. Petroleum production is resumed from an even lower portion of formation **12** via other perforations, not illustrated.

As will be apparent to those skilled in the many alterations, modifications and changes may be made in the practice of this invention in the light of the accompanying disclosure without departing from the spirit or scope of this invention.

I claim:

A method of producing petroleum via a well bore penetrating a subsurface petroleum-producing formation having a substantial thickness which comprises fracturing said formation at a location below the top and in the upper fraction of said formation to create a substantially horizontal fracture therein extending radially outward from said well bore, cementing the resulting fracture to render the same substantially gas impermeable thereby dividing said formation into an upper portion and a lower portion adjacent said well bore, dividing said well bore into an upper portion and a lower portion by setting a packer having production tubing extending therethrough above and adjacent said fracture and below the top of said formation, introducing a non-oxidizing gas under pressure via said upper portion of said well bore into said upper portion of said formation above the location of said fracture therein, and producing petroleum from said lower portion of said well bore from said lower portion of said formation via said production tubing in said well bore.

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