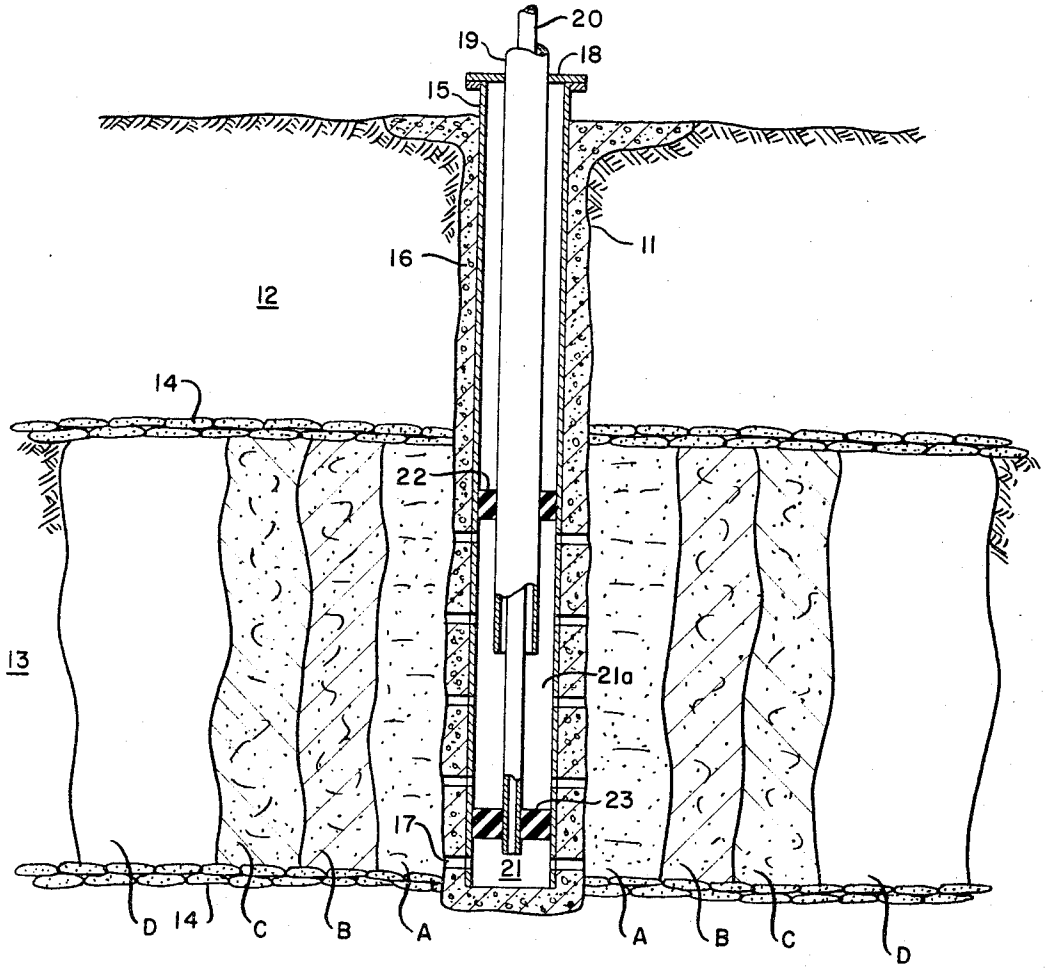
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PETROLEUM RECOVERY BY THERMAL BACKFLOW

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PETROLEUM RECOVERY BY THERMAL BACKFLOW

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1 Claim. (Cl. 166—40)

ABSTRACT OF THE DISCLOSURE

An improved backflow process for recovery of oil from an underground formation that contains both oil and water comprising establishing communication between a well borehole and said formation, thermal soaking the oil in the recovery zone by injecting steam and initiating an underground combustion therein to form non-condensable gas and additional steam and thereafter reducing the pressure within the well borehole to less than the formation pressure to allow fluid inclusive of oil to backflow into the well borehole.

Cross-references to related applications

This application is a continuation-in-part of copending application Ser. No. 421,294, filed Dec. 28, 1964, now U.S. Patent No. 3,333,637.

Background of the invention

The invention relates broadly to the recovery of petroleum from subterranean reservoirs by thermal backflow, and more particularly to a method of backflow recovering petroleum from underground formations wherein thermal soaking is accomplished by injecting steam and also initiating an underground combustion by injecting an oxygen-containing gas into the reservoir formation. The combustion products contain non-condensable fluids and these fluids as well as the combustion-produced steam are utilized in the recovery of petroleum by backflow techniques of the present invention. The primary source of the reservoir-heating fluid can come from the formation of steam in situ.

It is known that in many petroleum-bearing reservoirs only a small portion of the petroleum is recovered by primary recovery techniques which depend on natural gas or water pressure and/or gravity in the reservoir system to flow the petroleum into the borehole. When the pressure drops because of the removal of some of the petroleum or the petroleum is too viscous to be removed by these natural pressures in the reservoir system, primary recovery (natural flow) is not possible. Since there are substantial quantities of petroleum remaining in the reservoir in both such situations, supplemental recovery techniques are often employed to recover additional petroleum from the reservoir.

These supplemental techniques are sometimes referred to as "secondary recovery methods" and a useful dichotomy of these secondary methods are those involving "drives," such as waterfloods, and those involving backflow where the injection and recovery are accomplished from the same individual borehole. In the case of drives spaced wells are used and the petroleum is driven by injecting fluid into the reservoir at one location to create a pressure differential that causes fluid in the reservoir to move into a spaced recovery location. In backflow techniques, after fluid has been injected into the reservoir, the injected fluid and the petroleum is backflowed into the same well at the same location that was used for the injection of the fluid.

Each of the backflow and drive techniques has certain advantages over the other. The drive techniques have been generally preferred since they are usually more efficient in that the fluid is continually moved in the direction of the gradient that is first established within the reservoir; whereas, in the backflow techniques, the injected fluid must first bypass the oil and then displace the oil back into the opening through which the fluid was injected. The principal disadvantage of drives are the expense of drilling of additional wells, and locating such wells so that they encounter the same reservoir and the space between the wells is free of discontinuities caused by impermeable streaks, faulting and the like which would render the drives inoperable. While the backflow techniques avoid the above-mentioned disadvantages of the drives, in many instances the conventional backflow techniques have not been effective enough to offset the additional oil recovery obtained by drives. In general, the conventional backflow techniques are more efficient when they employ heated fluids in reservoirs containing an oil having a viscosity such that the hot fluid tends to bypass much of the petroleum around the well, but in doing so heats it to a temperature at which it may be more easily displaced into the well during the backflowing of the well. This beneficial effect tends to be lost where the oil viscosity is initially low enough to allow a large proportion of the oil to be displaced away from the well as the hot fluid is injected or where the hot fluid tends to "flash-off" light hydrocarbons and leave a viscous petroleum residue in the formation. In the latter situation the viscous residue may tend to plug some of the pores of the reservoir adjacent to the borehole and make the backflow more difficult.

Summary of the invention

In the process of the parent application backflow recovery of petroleum is accomplished by injecting a slug of non-condensable gas through a borehole into a petroleum-bearing reservoir, subsequently injecting a heated condensable fluid, then producing a fluid from the reservoir by reducing the pressure in the borehole to less than the pressure in the reservoir and recovering the petroleum that flows into the borehole.

The present invention is an extension or modification of the parent backflow process for petroleum recovery in respect to recovering petroleum from earth formations which contain both oil and water. The present process comprises:

(1) establishing fluid communication between a well and a portion of an earth formation which contains oil and water;

(2) heating a portion of the earth formation in the presence of oxygen and steam and initiating an underground combustion of the oil;

(3) injecting oxygen-containing gas through the well at a rate maintaining the combustion and displacing combustion products and steam into the earth formation beyond the combustion zone; and,

(4) reducing the pressure within the well to less than that within the earth formation beyond the combustion zone and producing oil from the well.

Description of preferred embodiments

The specified injection into an earth formation containing oil and water is not limiting from a practical point of view, since most oil-bearing earth formations contain sufficient water, usually to connate form.

The advantages of the present invention relative to conventional steam drive or underground combustion drive processes are essentially those of a backflow type of production as distinguished from a drive between a pair of wells.

Although the backflow process of the parent applica-

tion, i.e., using injection of non-condensable gas followed by injection of heated condensable fluids such as steam, is generally effective and economical in recovering petroleum, the process of the present invention offers additional advantages by providing (1) a means of effecting a steam soak type of production process in a location in which the water availability situation makes it undesirable to generate all of the steam at a surface location and (2) an attractive means of extending the depth of penetration obtainable in a steam soak operation, particularly when applied after a first cycle in which the injected fluid was steam or steam preceded by a slug of non-condensable gas.

Any suitable means for initiating in situ combustion of the oil in underground formations that contain oil and water can be used. The earth formation is preferably preheated with steam to a moderate temperature and ignition is preferably obtained by injecting steam containing at least about 20 percent air and utilizing the heat of the oil oxidation to supplement the heat needed to attain the ignition temperature. Where an earth formation has been previously heated by a prior injection backflow cycle as is, for example, described in the parent case, ignition can be attained by simply injecting a combustion-supporting gas such as oxygen, air, etc. In the former case spontaneous ignition in the formation can be achieved by use of a mixture of steam and air containing at least 20 percent by weight of air as the initiating combustion fluid. Instead of injecting a mixture of steam and oxygen-containing gas, the two fluids can be injected alternatively.

Once combustion has been initiated, the combustion zone can be advanced by injection of a mixture of air and water. The water injection helps control the temperature in the combustion front and controls or restricts cracking and coking as well as enhancing the depth of penetration of the heat zone thereby advantageously increasing the amount of oil that can be heated within a given time.

In general, after some steam has been injected, for example, to preheat, the oil for ignition and/or as a steam soak cycle, where the recovery zone being heated contains both oil and water, then the combustion front can advantageously be advanced by conventional dry procedures and/or by a procedure in which the temperature is controlled by limiting the quantity of the injected oxidizing gas used to support the combustion. Normally in a dry combustion process where water (connate) is present in the oil-bearing formation, an oxidizing gas is injected into the formation after a portion of the hydrocarbons in the formation has been raised to ignition temperature resulting in establishment of a combustion front which in time establishes in front of it a heated liquid condensate zone due to the presence of water which is vaporized and recondensed in the cooler areas of the formation. Also, some of the combustible gases which are formed during the combustion finger pass the condensated liquid zone and establish a non-condensable gaseous zone essentially as desired in the parent application. The combustion front may be controlled by limiting the quantity of injected oxidizing gas. The water formed by selective combustion of the hydrogen atoms from the residual hydrocarbons in the formation together with the water present in the pores of the formation is displaced in vapor form by means of the combustion gases away from the well bore. As the process proceeds temperature of the vapor drops, it condenses and the heat emitted therefrom heats oil-bearing zone.

In general, the oxygen-containing gas which is injected in order to initiate and maintain the combustion provides sufficient non-condensable gas to enhance a steam soak, by providing a gas-aided steam soak of the type described in the parent case. Once the combustion is initiated, it is maintained for a period of from several weeks to several months. The injection pressures are preferably kept below those corresponding to the weight of the overburden.

In the present process, the fluids which are injected tend to become distributed within the reservoir formation in the manner described in the parent case. During a given injection cycle, a localized pressurized zone is created within the portion of the reservoir formation in which fluid has time to move during the period in which fluid is being injected. The gaseous fluids which are injected or formed within the formation, being more mobile than liquids, tend to flow around and bypass much of the reservoir oil while displacing most of the liquid water further into the reservoir formation. The heated gases and steam give up their heat to the liquid and solid components of the reservoir formation and the steam condenses to become a liquid that is also bypassed by the non-condensable gases. The resulting fluid is distributed as illustrated by FIGURE 1.

Specifically, the figure is a vertical section through an earth formation showing a borehole traversing multiple strata and a reservoir wherein is illustrated the conditions encountered during the practice of the invention.

Brief description of the drawing

Referring to the drawing a borehole **11** penetrated from the surface through overburden strata **12** and a petroleum producing reservoir **13** which is sandwiched between impermeable layer **14**. The reservoir, though shown as a horizontal one, could have a reasonable degree of dip without effecting the practice of this invention.

A well casing **15** is shown secured in the borehole **11** with a sealant **16**, such as cement, and in the area of the vertical traverse of the reservoir **13** the casing string **15** and sealant **16** are perforated with ports **17** to provide fluid communication with the inside of the casing string **15** and the reservoir **13**.

At the top of casing string **15** a gland **18** secures the outer pipe string **19**, of two concentric pipe strings **19** and **20**, respectively, which extend downwardly inside the casing string. The inner pipe string **20** preferably extends to the bottom of the casing string **15**, extending below the end of the outer string **19**. The annulus between the casing string **15** and the inner pipe string **20** is sealed with packer **23** in the lower portion of the reservoir **13** so that there is a lower compartment **21** through which only the inner pipe string **20** has fluid communication with the reservoir **13**. The annulus between the outer pipe string **19** and the casing string **15** is sealed with packer **22** near the top of reservoir **13** and provides an upper compartment **21***a* through which the outer pipe string **19** has fluid communication with the reservoir **13**.

In this arrangement the lower compartment **21** communicating with the lower reservoir serves as a sump during backflow of petroleum to the borehole and either or both of the compartments can be used for injection. Such an arrangement is desirable in a reservoir in which there will be a significant gravity segregation of the fluids in the reservoir and/or where there is a difference in the permeabilities of the upper and lower portions of the reservoir, etc. This sump can also be used to prevent portions of the gaseous slug from moving back toward the borehole and venting prematurely into the casing string **15** by closing off pipe string **19** and recovering only through pipe string **20**.

In general, the arrangement of the well conduits for injecting fluids into and producing fluids from the reservoir formation should be designed for the optimum recovery from the particular formation being treated.

For a better understanding of the invention the oil recovery reservoir **13** is divided into zones A, B, C and D to show the conditions in the reservoir during the practice of this invention. As an oxygen-containing gas such as oxygen or air or mixtures of such gases and a fluid such as water is injected into the formation through the well borehole via tubing strings **19** and/or **20** to cause initiation of a combustion front, the upstream portion of

zone A becomes an oil-depleted zone through which a combustion-supporting fluid is conveyed to a combustion front bordering on zone B. In zone B a condensation front is established which comprises of a partially heated zone containing oil, condensate, steam and a small amount of gas. As the injection of oxygen-containing gas through the well is maintained at a rate to support combustion in the oil reservoir, the non-condensable combustion products are displaced into zone C. The zone D is a pressurized zone in which the formation fluid pressure becomes increased for the duration of the process due to the injection of fluid as described into the formation. The pressurized zone D enables the backflow of oil into the well conduits when pressure adjustments are made such as by lowering the pressures in the casing string **15** below a pressure existing between the borehole and the outer boundary of zone D. Further, the petroleum in bank B is heated more as it moves into the areas adjacent to the borehole where temperatures are higher which improves the mobility ratio still further.

Also, it may be desirable to reduce the pressure in borehole **11** after the residual pressures have been released by placing a partial vacuum thereon.

The method of the invention is especially effective when the petroleum does not originally contain high proportions of dissolved gas. Further, it should be appreciated that some steam will finger through the petroleum bank and aid the gaseous slug as a drive mechanism during backflow. As the pressure drops in the casing **15**, the gaseous slug sweeps toward the casing string **15** and the partial pressure of steam will be reduced and some of the water condensate will be flashed into steam to aid the drive mechanism in forcing the petroleum bank toward the borehole **11**.

I claim as my invention:

1. A method of recovering petroleum from a subterranean reservoir by a thermal backflow which comprises the steps of:

establishing fluid communication between a single well borehole and a reservoir that contains oil and water;

heating a portion of said reservoir in the presence of steam and oxygen-containing gas and initiating underground combustion of the oil;

injecting a combustion supporting mixture of water and oxygen-containing gas through the well at a rate sufficient to maintain combustion;

displacing gaseous combustion products and steam into the formation beyond the combustion zone;

terminating said injection of combustion supporting mixture of water and oxygen-containing gas and allowing the formation to thermally soak;

reducing the pressure within the well borehole to less than the pressure within the formation and producing oil from the well by backflow; and, repeating the heating, injecting, displacing, terminating and pressure reducing steps to produce additional amounts of oil.

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