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PRODUCING PLURAL SUBTERRANEAN STRATA BY
IN SITU COMBUSTION AND FLUID DRIVE
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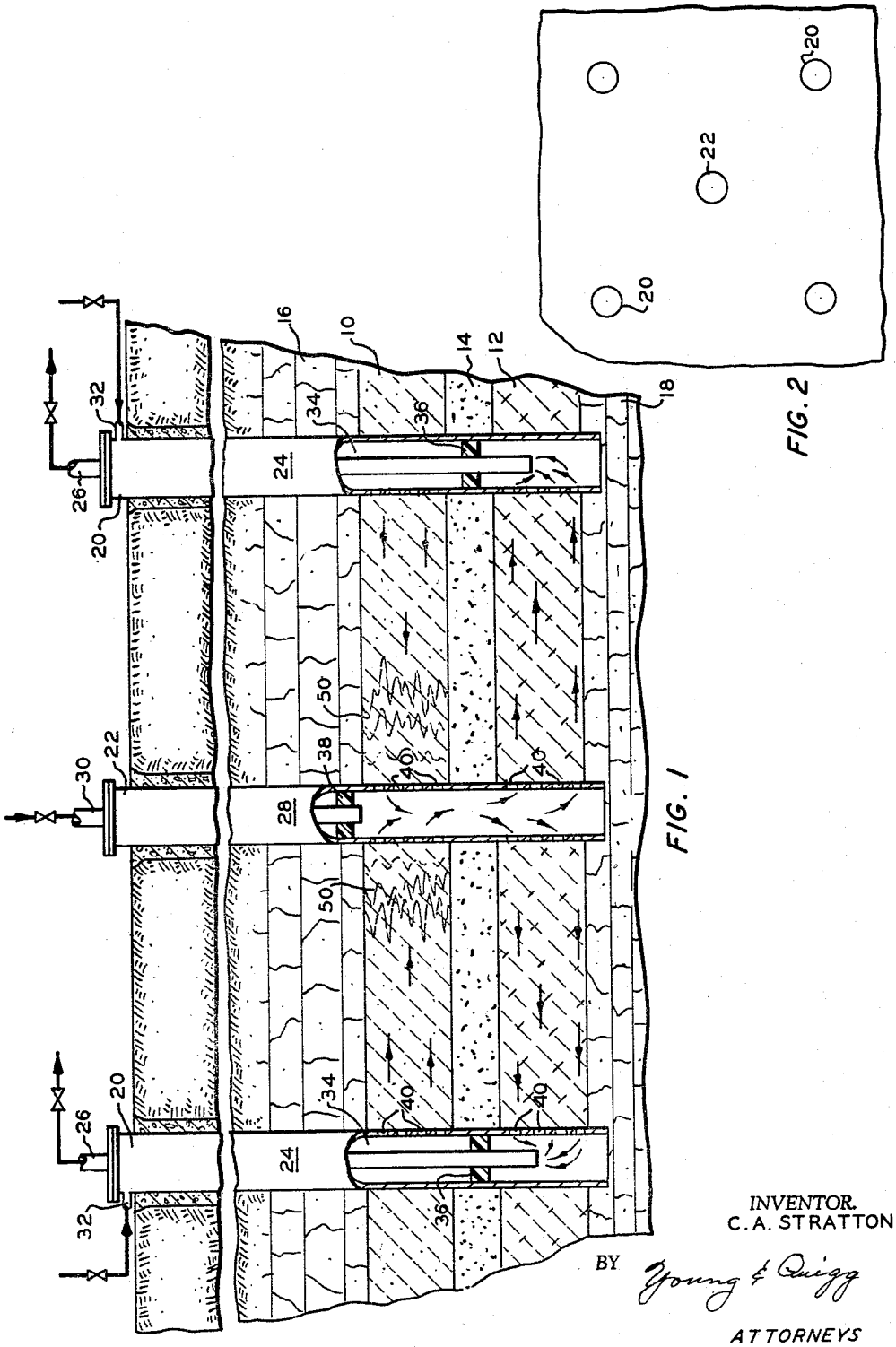

FIG. 1

FIG. 2

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PRODUCING PLURAL SUBTERRANEAN STRATA BY IN SITU COMBUSTION AND FLUID DRIVE

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This invention relates to a process for the production of oil from two or more subterranean strata by in situ combustion and fluid drive.

In oil fields found in various locations, such as in the Monagas Field in Venezuela and the Danglemeyer Lease of North Texas, different oil zones having oil in different viscosities are spaced apart by impermeable barriers or strata. A less viscous oil zone may overlie a more viscous oil zone or vice versa. Also, a more viscous oil zone may lie between adjacent less viscous oil zones from which they are separated by impermeable barriers. The less viscous oil zone may lie intermediate two or more viscous oil zones.

Accordingly, it is an object of the invention to provide an improved process for producing two or more spaced-apart, oil-bearing strata separated by permeable layers. Another object is to provide a process for producing such strata utilizing a combination of fluid drive and in situ combustion. A further object is to provide an arrangement of apparatus in wells penetrating spaced-apart strata containing oil of different viscosities for producing said strata. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises producing hydrocarbons from an oil field including a less viscous oil-bearing stratum and a more viscous oil-bearing stratum separated by an impermeable barrier and penetrated by a pair of wells, which comprises producing the less viscous oil-bearing stratum by fluid drive between said wells to partially deplete same, igniting the more viscous oil-bearing stratum around one of said wells to establish a combustion zone therein, driving the resulting combustion zone through the more viscous oil-bearing stratum toward the other well by feeding combustion-supporting gas thereto so as to produce a hot gaseous effluent comprising hydrocarbons and combustion gases in one of said wells, passing at least a substantial portion of said hot effluent directly from said one well through the partially depleted, less viscous oil-bearing stratum to the other well to produce additional hydrocarbons and recovering the produced hydrocarbon from said other well.

The less viscous oil-bearing stratum may be produced by any type of fluid drive, such as miscible fluid drive, water flooding, steam drive, or other gas or liquid drive not involving in situ combustion. The more viscous oil-bearing stratum is produced by either inverse or direct drive in situ combustion in a manner well known in the art. The gaseous effluent from the in situ combustion drive is passed directly from the production well through the partially depleted stratum containing the less viscous oil so as to produce additional oil therefrom and the hydrocarbons produced by both the in situ combustion step and the hot gas drive are recovered from one or more of the wells in the strata.

The less viscous oil-bearing strata referred to herein includes any stratum which contains oil sufficiently fluid to be produced by fluid flood in reasonable quantity, such as 10 to 15 or 20 percent of the oil in place. Oils of less than about 12 to 15 cps. are producible by fluid flooding in sufficient quantity for operation of the process. The more viscous oil-bearing strata referred to herein are those containing heavy oil or semisolid to solid hydrocarbon material not producible by fluid flooding but located in a stratum of sufficient permeability to permit moving a combustion zone therethrough by either direct or inverse injection of air. The less viscous oils usually have an API gravity of at least 20 or 25, while the more viscous oils have an API gravity of less than about 12.

A more complete understanding of the invention may be obtained by reference to the accompanying drawing of which FIGURE 1 is a fragmentary section through a formation or oil field showing one arrangement of apparatus for effecting the invention; and FIGURE 2 is a plan view of a 5-spot well pattern for producing oil from an oil field in accordance with the invention.

Referring to FIGURE 1, a more viscous oil-bearing stratum **10** is separated from a less viscous oil-bearing stratum **12** by an impermeable barrier **14**. These strata lie between an overburden **16** and a substratum **18**. All of these strata are penetrated by a pair of outer wells **20** and an intermediate well **22**. Outer wells **20** are provided with casing **24** and tubing string **26**, while intermediate well **22** is provided with casing **28** and tubing string **30**. Lines **32** connect with casing **20** and with the annulus **34** in wells **20**. Tubing strings **26** are extended to at least the level of impermeable barrier **14** and are surrounded by packers **36** which pack off the annulus above and below impermeable stratum **14**. A packer **38** may be provided around tubing string **30** and well **22**, if desired. The casing in each of the wells is provided with perforations **40** which serve as means for passing fluids between the wells and the strata as required in the process.

Referring to FIGURE 2, central well **22** is surrounded by four corner wells **20**. Wells **20** in FIGURE 1 may represent diagonally opposite wells **20** in FIGURE 2 and each may also represent one of the wells in two parallel lines of wells spaced from a line of central wells **22** for in-line production.

Utilizing the arrangement of apparatus shown in the drawing, less viscous oil-bearing stratum **12** is produced by fluid drive and by pumping in a conventional manner as by injecting fluid through tubing **30** and forcing same through stratum **12** into wells **20** from which production is recovered by pumping or pressure lift through tubing **26**. In this operation lines **32** must be kept closed so that injected fluid cannot pass through stratum **10** to annulus **34** of wells **20**. After partial depletion of stratum **12**, stratum **10** is ignited adjacent well **22** by any suitable means, and the resulting combustion zone is moved outwardly toward wells **20** by injecting combustion-supporting, O_2-containing gas, such as air, through lines **32** so as to move combustion zone **50** by inverse drive toward wells **20**. The hot produced gases pass into well **22** through perforations **40** leading into stratum **12** containing residual oil. The hot gases comprising hydrocarbons, combustion gas, and steam are forced through stratum **12** to wells **20** from which they are recovered, along with additional oil produced from stratum **12**, through tube string **26** in each of wells **20**.

It is feasible to produce a stratum containing highly viscous oil and one of low permeability by in situ combustion, particularly by inverse drive as illustrated in FIGURE 1 when the stratum is not amenable to production by fluid drive. The heating of the stratum by combustion of a portion of the oil raises the temperature thereof to a high level, such as 800 or 900° to 1400 or 1500° F., which renders the produced hydrocarbons substantially completely vaporous, thereby facilitating the drive of these vaporous hydrocarbons through the burned out, more permeable stratum behind the combustion zone. The hot vaporous effluent from the in situ combustion step provides an excellent gas for a gas drive through the partially depleted stratum containing less viscous oil.

In oil fields where stratum **10** contains oil of intermediate viscosity and sufficient permeability is available in this

stratum, the combustion zone may be driven through the stratum by direct drive. In this case, either combustion zones are established adjacent wells **20** and air is injected through lines **32** or well **22** is equipped with a line **32** and a packer **36** around tubing **30** at the level of stratum **14** so that air can be injected through line **32** (connected with casing **28**) so as to drive combustion zone **50** by direct drive through stratum **10** into wells **20** from which the hot gas is forced into stratum **12** by omitting packers **36** in wells **20**. In this type of operation the arrangement of tubing and packers in wells **20** and well **22** is reversed so that produced gases are driven from stratum **10** into wells **20** from which these gases pass directly into stratum **12** and are produced through tubing **30** which is extended below or at least to the level of stratum **14**.

Where production is effected by means of three rows of in-line wells, the same techniques may be applied. It is to be understood that it is not necessary to produce all of the effluent gas from the in situ combustion step in stratum **10** through stratum **12**. A portion of this hot effluent may be passed through a third stratum (partially depleted) lying above the stratum **10**, or below stratum **12**. In the event the third stratum lies above stratum **10**, packer **38** must be placed above this third stratum. It is also feasible to simultaneously produce more than one stratum, such as **10**, by in situ combustion and force all of the produced gases through one or more partially depleted strata in the same field.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

I claim:

1. A process for producing hydrocarbons from an oil field including a first permeable stratum containing liquid oil of relatively low viscosity and a second permeable stratum containing liquid oil of relatively high viscosity, said first and second strata being separated by an impermeable barrier and penetrated by a pair of wells, which comprises the steps of:

(1) substantially partially depleting the oil from said first stratum by fluid drive to recover oil therefrom and render same more permeable;

(2) igniting the liquid oil along the vertical extent of said second stratum around one of said wells to establish a combustion zone coextensive vertically with stratum;

(3) driving the combustion zone of step (2) thru the second stratum by feeding combustion-supporting gas thereto thru the pores of the permeable stratum so as to sweep a full cross section of the stratum and produce a hot gaseous effluent in one of said wells comprising a substantial proportion of oil and combustion gases;

(4) passing at least a substantial proportion of the hot effluent of step (3) directly from said one well thru the partially depleted stratum of step (1) to the other well to produce additional oil from last said stratum; and

(5) recovering oil produced from both strata from last said other well.

2. The process of claim 1 wherein said combustion-supporting gas is injected thru said other well so as to move said combustion zone by inverse drive thru said second stratum.

3. The process of claim 1 wherein said combustion-supporting gas is injected thru said one of said wells so as to move said combustion zone by direct drive thru said second stratum.

4. The process of claim 1 wherein said fluid drive comprises a miscible fluid drive.

5. The process of claim 1 wherein said fluid drive comprises water flood.

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