

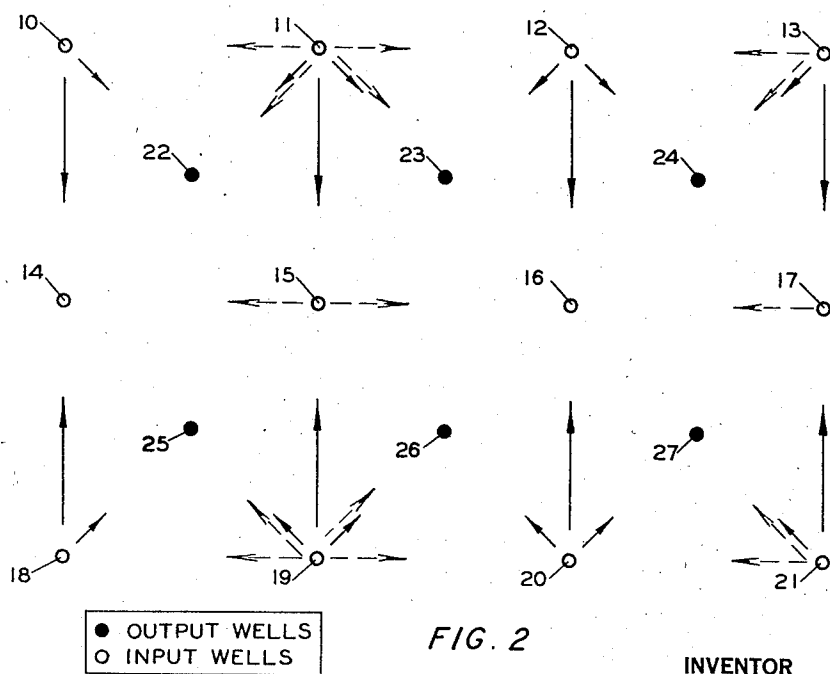
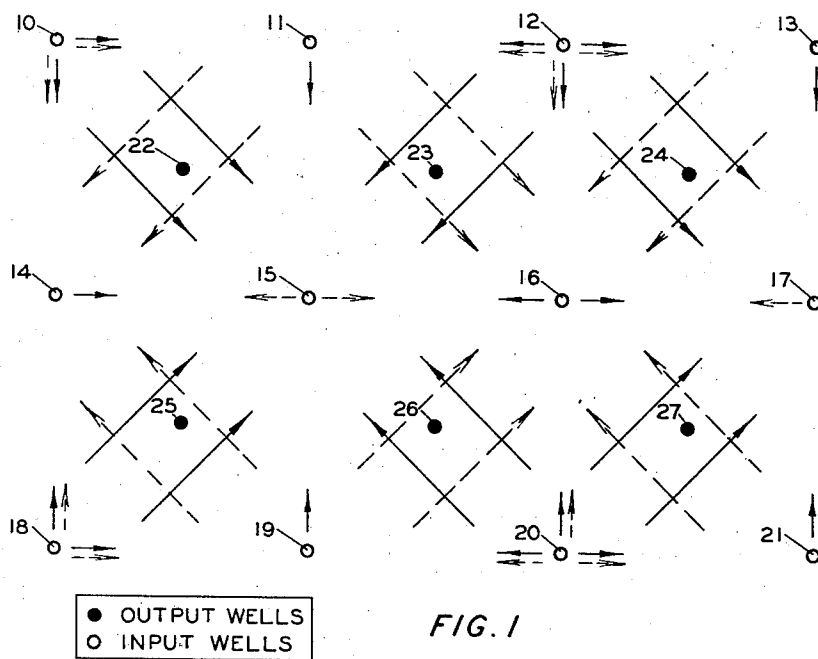
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METHOD OF RECOVERING HYDROCARBONS

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METHOD OF RECOVERING HYDROCARBONS

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This invention relates to the recovery of hydrocarbons from partially depleted oil sands; more particularly, it relates to an improved method of secondary recovery of oil from oil-bearing strata by a novel method of fluid-drive.

The recovery of oil from a subsurface formation may be accomplished by several means. The oil may be produced by natural means, such as gas or rock pressure, natural water drive, or solution gas pressure. When these natural forces are insufficient to cause the oil to flow from producing wells at an economical rate, the oil may be pumped or raised by one of the known methods. When pumping methods or the like can no longer produce oil at an economical rate, additional oil may be recovered by the application of secondary recovery methods, for example, water-flooding, fluid-drive, or repressuring of the partially depleted oil-bearing formation. These methods usually involve injection of water, gas, air, or other fluid or combination of fluids, into the formation through one or more input wells and production of oil from one or more output wells. The method disclosed herein is primarily concerned with the recovery of an additional amount of oil from the formation.

An object of this invention is to recover oil from an underground reservoir.

One of the objects of the present invention is to provide a method of increasing the ultimate oil recovery from a given structure containing oil.

A further object of this invention is to provide a novel method of fluid-drive which will effectively increase the recovery of oil from an oil-bearing formation.

A still further object of this invention is to provide a method of fluid-drive whereby oil is not permanently trapped in the formation as a result of the injected fluids flowing continuously toward an output well from one direction.

These and additional objects and advantages will be apparent to persons skilled in the art by reference to the following description and annexed drawing, wherein

Figure 1 is a diagrammatic view illustrating the general working of my instant invention; and

Figure 2 is another diagrammatic view illustrating the general working of a modification of my invention.

Referring to the drawing and more particularly to Figure 1, I have shown a plurality of input wells by reference numerals 10 to 21, inclusive, and a plurality of output wells by reference numerals 22 to 27, inclusive. It is to be noted from the drawing that the input and output wells are

arranged in a geometric pattern, which is known to those skilled in the art as a "five-spot" pattern. The five-spot pattern is the most frequent arrangement of input and output wells employed in fluid-drive operations. It is to be understood, however, that wells 10 to 27, inclusive, may be arranged to form other types of input and output well patterns wherein my instant method may be successfully practiced.

Prior to the initiation of my method, fluid is injected into the input wells, through which the injected fluid travels downwardly to the oil-bearing formation and thence outwardly through the formation toward the output wells. Oil, which is moved toward the output wells by the injected fluid, is pumped or lifted by any desired means to the surface of the ground. The fluid injected into any one input well at a desired superatmospheric pressure, which is determined by the existing reservoir conditions, flows outwardly through the formation, urging oil toward the output wells. The effect of the injected fluid is primarily a drive to the surrounding output wells, for example, in a "five-spot" pattern of well arrangement, fluid injected into input well 15 urges oil toward output wells 22, 23, 25, and 26. Also, any one output well is influenced by fluid injected into the surrounding input wells, for example, input wells 10, 11, 14, and 15 urge oil toward output well 22. The fluid, which is injected into the formation, flows from the input to the output wells through the connected pore spaces of the formation. In many hydrocarbon-bearing formations, pore spaces, which although interconnected for considerable lateral extent of the formation, are closed or plugged by cross-bedding planes, including a type whereby an impervious streak or vein of rock cuts across the formation in a vertical or slopping manner, or plugged by sediments and the like which are deposited during a fluid-drive secondary recovery operation. The interconnected pores which may be plugged due to either of these or other causes will hereinafter be referred to as "dead-end" or "blind" pores. The interconnected pores are usually plugged in localized parts of the formation, providing a region of "blind" pores adjacent to regions of open pores. Hydrocarbon oil, which is urged toward the output wells by the injected fluid, enters both the regions of "blind" pores and the regions of open interconnected pores. Hydrocarbon oil flows through the region of "blind" pores until the resistance to flow of fluid therein exceeds the resistance to flow in the open interconnected pores, whereupon the flow of fluid in the reser-

voir is by way of the open pores. Thus, fluid, which has entered or which was already contained in the "blind" pores becomes trapped therein, from which it cannot be recovered unless the principal direction of fluid flow in the reservoir is changed.

In order to change the direction of flow of the injected fluid and thereby recover the oil which is trapped in the "blind" pore regions of the formation, I shut in output wells 22, 23, 24, 25, 26, and 27, withdrawing no fluid therefrom; I open input wells 15 and 17 to the atmosphere so that the pressure on the well approaches atmospheric pressure; I maintain input wells 10, 12, 18, and 20 at a superatmospheric injection pressure of P ; I maintain a reduced superatmospheric pressure of p , on input wells 11, 13, 14, 16, 19, and 21. This reduced pressure, p , may be any desired superatmospheric pressure less than pressure P , however, I have found that by maintaining the reduced superatmospheric pressure approximately one-half of the injection pressure I obtain satisfactory performance of my method. By thus adjusting the pressures on the input wells, the principal movement of fluid through the reservoir will be in the general direction of input wells 15 and 17, as indicated by the large full arrows on Figure 1. A minor movement of fluid also takes place between the input wells which are subjected to pressure P and the input wells which are subjected to pressure p . There is also a minor movement of fluid between this latter group of wells and the input wells which are open to the atmosphere. These minor movements are indicated by the small full arrows on the drawing. It will be noted that the direction of flow from all input wells is changed, excepting that from wells 10, 12, 18, and 20. By changing the direction of movement of fluid through the reservoir for a predetermined length of time, as predicted by the reservoir conditions, hydrocarbon oil which was trapped in the "blind" pores by the movement of fluid through the reservoir previous to the initiation of my instant method is removed from those pores and is caused to flow into the open interconnected pore spaces through which it may be urged to the output wells, when the conventional method of fluid-drive is resumed. Prior to resuming the conventional method of fluid-drive, a step in which input wells 14 and 16 are opened to the atmosphere is practiced, wells 11, 13, 19, and 21 are subjected to superatmospheric pressure P ; and wells 10, 12, 15, 17, 18, and 20 are subjected to superatmospheric pressure, p . Thus, the general direction of the principal movement of fluid in the reservoir, which is also maintained for a predetermined length of time, is toward input wells 14 and 16, as indicated by the large broken arrows. It is to be noted that the direction of the principal movement of fluid in the reservoir, which is toward input wells 14 and 16 that are opened to the atmosphere, is substantially across the direction of the principal movement of fluid resulting from input wells 15 and 17 being opened to the atmosphere. Minor movements of fluid in the reservoir also take place between those input wells which are subjected to pressure P , and those which are subjected to pressure p , and between the latter input wells and input wells 14 and 16, as indicated by the small broken arrows. During the step of my instant invention in which input wells 14 and 16 are opened to the atmosphere, hydrocarbon oil which has been trapped in the "blind" pores that occur in the formation between input wells 10, 12, 18, and 20

and the output wells is caused to flow to the open interconnected pores through which the oil is urged to the output wells, when the conventional method of fluid-drive is resumed. After the direction of fluid movement in the reservoir has been changed by the steps as set forth, all input wells are subjected to the superatmospheric pressure P , and hydrocarbon fluid is withdrawn from output wells 22, 23, 24, 25, 26, and 27. Fluid is injected into all input wells until it again becomes necessary to repeat the steps of my instant invention.

Turning next to Figure 2 for a description of a modification of my instant invention, it will be noted that the input and output wells are designated by the same reference numerals as in Figure 1. When it is desired in the practice of fluid-drive operations to apply this modification, output wells 22, 23, 24, 25, 26, and 27 are shut in. Input wells 14, 15, 16, and 17 are opened to the atmosphere and sufficient fluid is injected into input wells 10, 11, 12, 13, 18, 19, 20, and 21 to maintain a superatmospheric pressure P , thereon. This pressure is preferably that at which normal fluid-drive operations were carried out. The movement of fluid in the reservoir is effected between the last mentioned group of input wells and the input wells which are opened to the atmosphere for a predetermined length of time as predicated by the reservoir conditions in order to remove hydrocarbon oil from the "blind" pores. The general direction of the movement of the fluid in the reservoir is indicated by the large full arrows on Figure 2. Minor fluid movements are generally indicated by the small full arrows on Figure 2. Next input wells 10, 14, 18, 12, 16, and 20 are opened to the atmosphere and input wells 11, 15, 19, 13, 17, and 21 are subjected to the superatmospheric pressure P , and fluid is moved through the reservoir toward the input wells which are open to the atmosphere, as generally indicated by the broken arrows. When the hydrocarbon oil, which has been trapped in the "blind" pores of the formation has been removed therefrom to the open interconnecting pore spaces, fluid is again injected into input wells 10, 14, 18, 12, 16, and 20, increasing the pressure on these wells to superatmospheric pressure P while continuing to maintain the remaining input wells, namely, wells 11, 15, 19, 13, 17, and 21 at said superatmospheric pressure, P ; output wells 22, 23, 24, 25, 26, and 27 are opened up to production; and normal fluid-drive operations are resumed. When oil again becomes trapped in the "blind" pores, the practice of this modification of my invention may be resumed.

From the foregoing, it is believed that the many advantages obtainable by the practice of the present invention will be readily apparent to persons skilled in the art. However, since certain changes may be made in carrying out the above method without departing from the scope of the invention as defined by the appended claims, it is intended that all matter contained herein shall be interpreted as illustrative and explanatory, rather than in a limiting sense.

I claim:

1. In a method of recovering hydrocarbons from a hydrocarbon-bearing formation that is substantially devoid of natural fluid energy and that is penetrated by a plurality of input wells and at least one output well, the steps comprising shutting in the output well, injecting fluid under pressure into the formation through at least one input well to effect movement of hydro-

carbons through the formation in one general direction and toward the output well, subsequently injecting fluid under pressure into the formation through at least another input well to effect movement of hydrocarbons through the formation toward the output well in a general direction that is across the direction of movement effected by the preceding step, and opening the previously shut-in well and withdrawing fluid from the formation therethrough.

2. In a method of recovering hydrocarbons from a hydrocarbon-bearing formation that is substantially devoid of natural fluid energy and that is penetrated by a plurality of input wells and at least one output well, the steps comprising shutting in the output well, injecting fluid under pressure into the formation through at least one input well while maintaining the pressure on at least another of the input wells at an inferior pressure to obtain directional fluid drive and movement of hydrocarbons through the formation and toward the output well, subsequently injecting fluid under sufficient pressure into the formation through at least one input well other than the first mentioned input well to obtain fluid drive and movement of hydrocarbons through the formation and toward the output well across the fluid drive and movement of hydrocarbons obtained in the second step, and then withdrawing fluid from the formation through the previously shut-in output well.

3. In a method of recovering hydrocarbons from a hydrocarbon-bearing formation that is substantially devoid of natural fluid energy and that is penetrated by a plurality of input wells and at least one output well, the steps comprising shutting in the output well, injecting fluid under superatmospheric pressure into the formation through at least one input well while maintaining at least another of the input wells at substantially atmospheric pressure to obtain directional movement of the hydrocarbons through the formation and toward the output well, subsequently injecting additional fluid under sufficient pressure into the formation through at least one input well other than the first mentioned input well to obtain movement of the hydrocarbons through the formation and toward the output well across the movement of the hydrocarbons obtained in the second step, and then opening the previously shut-in output well and recovering fluid therethrough.

4. In a method of recovering hydrocarbons from a hydrocarbon-bearing formation that is substantially devoid of natural fluid energy and that is penetrated by a plurality of input wells and at least one output well, the steps comprising shutting in the output well, injecting fluid under superatmospheric pressure into the formation through at least one input well while maintaining at least another of the input wells at substantially atmospheric pressure to obtain directional movement of the hydrocarbons through the formation and toward the output well, subsequently injecting additional fluid under superatmospheric pressure into the formation through at least one input well other than the first mentioned input well while maintaining another of the input wells at substantially atmospheric pressure to obtain movement of the hydrocarbons through the formation and toward the output well in a direction across that obtained in the second step, and then opening the previously shut-in output well and recovering fluid there-through.

5. The method of working an oil field to recover oil from a partially depleted oil-bearing formation that is substantially devoid of natural fluid energy and that is penetrated by a plurality of input wells and output wells comprising shutting in the output wells, injecting fluid under superatmospheric pressure into the formation through a group of input wells while maintaining at least one input well at reduced pressure to move oil in the formation towards one part of the field, subsequently injecting fluid under superatmospheric pressure into another group of input wells to move oil in the formation toward another part of the field, and withdrawing oil through at least one output well.

6. The method of working an oil field to recover oil from a partially depleted oil-bearing formation that is penetrated by a plurality of input wells and output wells comprising shutting in the output wells, injecting fluid under superior superatmospheric pressure into the formation through a group of input wells, simultaneously injecting fluid under inferior superatmospheric pressure into the formation through a second group of input wells while maintaining a plurality of the input wells at a pressure below said inferior superatmospheric pressure to move oil through the formation toward one part of the field, subsequently injecting fluid under superior superatmospheric pressure into the formation through a third group of input wells, simultaneously with the preceding step injecting fluid under inferior superatmospheric pressure into the formation through a fourth group of input wells to move oil through the formation toward another part of the field, and withdrawing oil through output wells.

7. The method of working an oil field to recover oil from a partially depleted oil-bearing formation that is penetrated by a plurality of input wells and output wells comprising shutting in the output wells, injecting fluid under superior superatmospheric pressure into the formation through a group of input wells, simultaneously injecting fluid under inferior superatmospheric pressure into the formation through a second group of input wells while maintaining a plurality of the input wells at atmospheric pressure to move oil through the formation toward one part of the field, subsequently injecting fluid under superior superatmospheric pressure into the formation through a third group of input wells, simultaneously with the preceding step injecting fluid under inferior superatmospheric pressure into the formation through a fourth group of input wells to move oil through the formation toward another part of the field, and then withdrawing oil through the output wells.

8. The method of working an oil field to recover oil from a partially depleted oil-bearing formation that is penetrated by a plurality of input wells and output wells comprising shutting in the output wells, injecting fluid under superatmospheric pressure into the formation through one group of input wells while maintaining another group of input wells at a pressure below said superatmospheric pressure to move oil through the formation toward one part of the field, subsequently injecting fluid under superatmospheric pressure into the formation through a third group of input wells to move oil through the formation toward another part of the field, and withdrawing oil through output wells.

9. The method of working a partially depleted oil-bearing formation that is penetrated by at

least three input wells that are spaced substantially equidistant and one output well positioned substantially centrally of the input wells comprising shutting in the output well, injecting fluid under superior superatmospheric pressure into the formation through at least one input well while maintaining at least one input well at atmospheric pressure, simultaneously injecting fluid under inferior superatmospheric pressure into the formation through at least one input well to obtain movement of oil through the formation in one general direction and toward the

output well, injecting fluid under superatmospheric pressure that is greater than the pressure mentioned in the preceding step into the formation through at least one input well first mentioned other than the well referred to in the second step to obtain movement of oil through the formation and toward the output well in a general direction which crosses the above mentioned direction of movement, and then opening the previously shut-in output well and withdrawing oil therethrough.

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