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METHOD FOR INJECTING AND RECOVERING FLUIDS FROM A FORMATION

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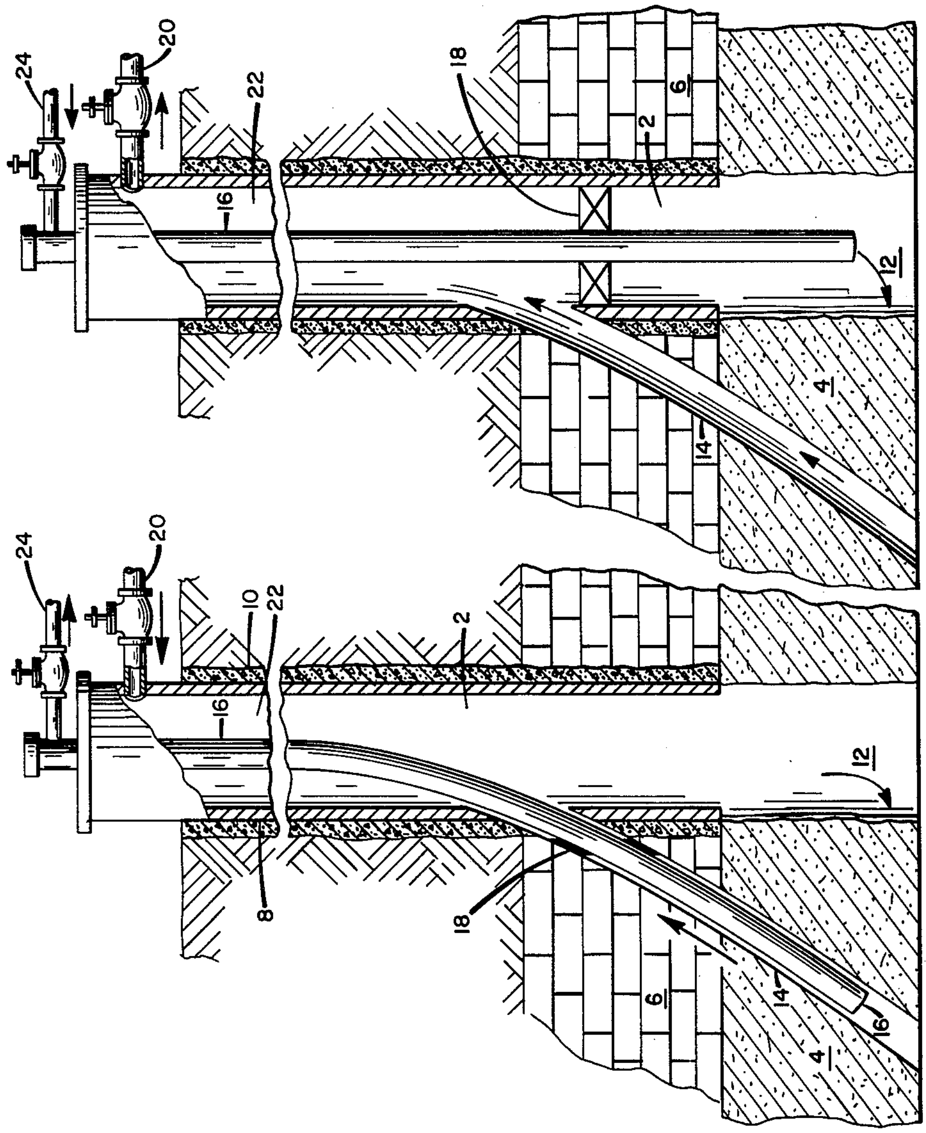

FIGURE-2

FIGURE-1

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METHOD FOR INJECTING AND RECOVERING FLUIDS FROM A FORMATION

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The present invention relates to a novel method for making a pilot test from a single well head prior to conducting a secondary, or tertiary, recovery operation to produce hydrocarbons from a subterranean reservoir. More particularly, it is concerned with a relatively inexpensive procedure for determining the advisability of subjecting a given hydrocarbon-containing reservoir to injection with a fluid such as may be employed in flooding or underground combustion operations.

Briefly, the process of my invention involves first drilling and completing a well to the producing zone in the usual fashion. In this connection, the well may be cased the entire length of the hole, and perforations made opposite the producing zone or, if considered expedient, casing need only be run to the top of the pay. Thereafter, at a level in the casing, typically several hundred feet above the bottom of the well, a second well is drilled by the aid of a whipstock, or a similar device, at an angle from the main well down into the pay in which the conventional well was completed. When the directional well is drilled to the desired depth, tests may be started. By injecting the test fluid such as, for example, water, LPG or air, into the open hole and collecting the test fluid through the directional well, or vice versa, the permeability and other properties of the formation to be flooded or otherwise treated can be readily established. The duration of the test depends, generally, upon the distance between the two wells which terminate in the same oil sand, and the rate at which the test fluid or fluids are injected. Generally, such tests, in a period of thirty to forty days, gives sufficient information to determine whether or not the procedure on a larger scale will be practicable.

FIGURE 1 in the drawings shows a well traversing a series of formations and terminating in an oil-producing sand with a directional well extending into said sand and offset from the main well.

FIGURE 2 is a variation of the system shown in FIGURE 1, in which fluid is injected into the formation via the directional well, and formation fluids collected in the open hole of the main well and recovered.

In any process other than in the case of primary recovery, preliminary studies of the reservoir into which a fluid is to be injected should be made in order to determine the flooding system that will yield the highest recovery. In the case of underground combustion, it is desirable to establish the permeability of the reservoir with respect to air, so that one can determine whether or not sufficient oxygen can be supplied to sustain a burning front.

Ideally, it would be desirable to make such studies under conditions identical with those prevailing in the reservoir; however, in the past this has not been possible. Usually, characteristics of the reservoir were best determined by taking a core of the formation under investigation, forcing certain fluids through it, and from the results thus obtained arriving at a flooding system considered most suitable for the recovery operation contemplated. One chief difficulty with core studies, however, is that it is practically impossible to obtain a core having properties identical to the reservoir rock in its natural state. This is true because in obtaining such a core, its permeability is altered to some extent by invasion of drilling mud during the coring operation.

Ordinarily, when a secondary recovery operation of the above mentioned type is planned, and after all information has been obtained that can be secured by means of core tests, a pilot flood, involving usually 5 or 10 acres, is initiated. Even with such a small-scale test, is is generally at least a year before the information necessary for successful performance of the main secondary recovery operation can be obtained. Such an extended period for the procurement of preliminary information not only is expensive to conduct, but the results may indicate a large-scale flood is not feasible, in which case valuable time has been wasted in pursuing an unprofitable project.

One of the outstanding advantages of the process of my invention is that valuable information of the type required to determine whether large-scale flooding operations should be conducted can be determined under natural reservoir conditions within a relatively short time. A very desirable feature of my invention is that I am able to accomplish a task, and obtain information from a single well head, that in the past required the drilling of at least two separate wells. Usually, tests of this sort were piloted using systems calling for five wells, i.e., the familiar five-spot pattern. Also, by operating in accordance with the present invention the flooding agent is able to contact a large area around the well in a short time. By monitoring the composition of the produced stream, information is provided from which an evaluation of the formation properties can be made. For instance, if it is desired to introduce an additive into the flooding agent, say for the purpose of effecting a change in wettability characteristics of the reservoir rock, one must know whether or not such additive tends to be adsorbed on the rock when the latter is contacted by the flooding agent. Accordingly, by plotting the composition of the product stream from the pilot test versus time, a measure of the total reservoir volume contacted can be determined. Also, by determining the amount of additive recovered in the product stream, the quantity thereof adsorbed on the rock surface can be ascertained. This information then will indicate how much additive is needed for the main flooding operation in which the reservoir volume, as a result of said pilot test, is known.

A further advantage of my invention resides in the fact that a number of different agents can be tested from a single well head to determine the behavior of such agents in the reservoir during a flooding operation. Between such tests, the formation affected is flushed free of previously-injected fluid by the use of air or gas and then reconditioned by injecting formation crude in an amount corresponding to the concentration in place before testing. Thereafter, injection of a different test fluid may be carried out.

The process of my invention will be further illustrated by reference to FIGURE 1, in which a well 2 penetrates an oil-bearing formation 4 under cap rock 6. Casing 8, supported by cement 10, extends to the top of formation 4 to leave an open hole section 12. After the casing in well 2 has been properly cemented, a whipstock is placed opposite the level at which it is desired to drill directionally through the casing and into formation 4. In this type of drilling, it ordinarily is possible to vary the angle of the whipstocked hole a maximum of about 5° from the vertical axis of the main well for each 100 vertical feet. Accordingly, if one wished to employ a system similar to that illustrated in FIGURE 1 in which the wells were, for example, 15 feet apart, the whipstocked hole should be started at about 175 feet above the bottom of open hole section 12. For a distance of 60 feet between wells, the whipstocking operation should start about 350 feet above the bottom of the open hole section. Generally, it may be said that the minimum distance between the bottom of the directional well and the bottom of the main well should be sufficient to avoid harmful effects resulting from invasion of drilling mud into the formation. Typically, this minimum distance should be from 10 to 15 feet. However, in the case of wells in which the producing formation was drilled using gas as the circulating fluid, this distance may be even less. In the majority of cases, the two wells in the oil-bearing formation are preferably from about 25 to about 50 feet apart.

Once directional well **14** is drilled, tubing **16** is run into it, preferably with the aid of a whipstock or similar tool, and a substantially fluid-tight seal made between tubing **16** and the walls of well **14** by means of production packer **18**. Injection tests may then be begun in which a fluid such as air, steam, water, etc., is introduced through line **20** under pressure into annulus **22**, and then into formation **4**. Under these conditions the injected fluid advances toward well **14** and formation fluid thus moved produced through tubing **16** and out of the well via line **24**. The volume and composition of the fluid thus removed are then determined. While such information is being obtained, injection of the desired flooding agent may be continued. As previously mentioned, the operation may require thirty to forty days before a satisfactory study of the produced fluids can be made. Eventually, a breakthrough of flooding agent into well **14** occurs. Injection of said agent is continued until the ratio of said agent to oil has increased to a maximum beyond a practical level.

In FIGURE 2, production tubing **16** is not whipstocked, but extends to a point near the bottom of open hole section **12**. Tubing **16** carriers a packer **18** located just below the level at which directional well **14** opens into well **2**. With a system such as that shown in FIGURE 2, the test fluid or fluids are introduced into formation **4** through line **24** and tubing **16**. The driven oil, as well as the driving fluid, advance toward well **14**, flow cut thereof, and are produced via annulus **22** and line **20**. Of course, if desired, the flow of fluids could be reversed with the production being removed via tubing **16** and line **24**.

Further, information as to directional premeability may be found by drilling additional angular wells in different directions, but all terminating in producing sand **4**. Such tests should be conducted with only one directional well open at a time. Determination of directional permeability of a producing formation is extremely important in any secondary recovery operation. Thus, if injection of the flooding agent is conducted under conditions such that said agent travels through the reservoir in the direction of greatest permeability, early breakthrough of the flooding agent occurs, causing poor recovery. On the other hand, if the flooding agent is injected in such a way so that it tends to follow a path essentially perpendicular to the direction of greatest permeability, breakthrough of the flooding agent is delayed, resulting in good oil recovery. Also, information as to the permeability of a reservoir can be determined by observing the pressure transient on one of the wells while a given transient is imposed on the other well.

It will be apparent that the process of my invention may be modified substantially without departing from the scope thereof. For example, if desired, a major flooding or other fluid injection project could be carried out in accordance with my invention in place of the pilot test mentioned above. Conceivably, in a large-scale operation several of these wells with directional holes could be drilled, and the process of the present invention employed at a cost much below that needed for drilling the requisite number of conventional wells to accomplish the same result.

I claim:

1. A method for recovering fluids from a petroleum reservoir which comprises drilling a first well and extending the latter into said reservoir, thereafter drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, injecting a test fluid into said reservoir via one of said wells, permitting said fluid to be produced into the other of said wells, and recovering the fluids thus produced including said test fluid from said other of said wells.

2. A method for recovering fluids from a petroleum reservoir which comprises drilling a first well and extending the latter into said reservoir, thereafter drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, said directional well being started at a level in said first well sufficiently high so that the distance between said wells in said reservoir at their respective bases is a minimum of about 10 feet, injecting a test fluid into said reservoir via one of said wells, permitting said fluid to be produced into the other of said wells, and recovering the fluids thus produced including said test fluid from said other of said wells.

3. The method of claim 2 in which the injected fluid is steam.

4. The method of claim 2 in which the injected fluid is water.

5. The method of claim 2 in which the injected fluid is air.

6. The method of claim 2 in which the injected fluid is LPG.

7. A method for recovering fluids from a petroleum reservoir which comprises drilling a first well and extending the latter into said reservoir, thereafter drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, said directional well being started at a level in said first well sufficiently high so that the distance between said wells in said reservoir at their respective bases is a minimum of about 10 feet, injecting a test fluid below said level into said reservoir via said first well, permitting said fluid to be produced into said directional well, and thereafter recovering the fluids thus produced including said test fluid from said directional well via said first well.

8. A method for obtaining information on a hydrocarbon-containing reservoir traversed by a first well prior to subjecting said reservoir to a procedure in which a fluid is to be injected into said reservoir which comprises, drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, said directional well being started at a level in said first well sufficiently high so that the distance between said wells in said reservoir at their respective bases is a minimum of about 10 feet, injecting a test fluid into said reservoir via one of said wells, permitting said fluid to be produced into the other of said wells, determining the time required for said injected fluid to break through into said other of said wells, recovering the fluids thus produced including said test fluid from said other of said wells, and monitoring the composition and volume of the produced fluids, whereby the characteristics of said reservoir can be determined.

9. A method for obtaining information on a hydrocarbon-containing reservoir traversed by a first well prior to subjecting said reservoir to a procedure in which a fluid is to be injected into said reservoir which comprises, drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, said directional well being started at a level in said first well sufficiently high so that the distance between said wells in said reservoir at their respective bases is a minimum of about 10 feet, injecting a test fluid below said level into said reservor via said first well, permitting said fluid to be produced into said directional well recovering the fluids thus produced including said test fluid from said directional well, and monitoring the composition and volume of the produced

fluids, whereby the characteristics of said reservoir can be determined.

10. A method for obtaining information on a hydrocarbon-containing reservoir traversed by a first well prior to subjecting said reservoir to a procedure in which a fluid is to be injected into said reservoir which comprises, drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, said directional well being started at a level in said first well sufficiently high so that the distance between said wells in said reservoir at their respective bases is a minimum of about 10 feet, injecting a test fluid below said level into said reservoir via said first well, permitting said fluid to be produced into said directional well, recovering the fluids thus produced including said test fluid while continuing the injecting of said test fluid into said reservoir via said first well, and montoring the composition and volume of the produced fluids, whereby the characteristics of said reservoir can be determined.

11. A method for recovering fluids from a petroleum reservoir which comprises drilling a first well and extending the latter into said reservoir, thereafter drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, said directional well being started at a level in said first well sufficiently high so that the distance between said wells in said reservoir at their respective bases is a minimum of about 10 feet, injecting a test fluid into said reservoir via said directional well, permitting said test fluid to be produced into said first well, and recovering produced fluids therefrom including said test fluid.

12. A method for obtaining information on a hydrocarbon-containing reservoir traversed by a first well prior to subjecting said reservoir to a procedure in which a fluid is to be injected into said reservoir which comprises, drilling a directional well from an intermediate level in said first well into said reservoir and to a depth approximately equal to that of said first well, said directional well being started at a level in said first well sufficiently high so that the distance between said wells in said reservoir at their respective bases is a minimum of about 10 feet, injecting a test fluid into said reservoir via said directional well, permitting said test fluid to be produced into said first well, determining the time required for said injected fluid to break through into said first well, recovering the fluids thus produced including said test fluid while continuing the injection of said test fluid into said directional well, and monitoring the composition and volume of the produced fluids, whereby the characteristics of said reservoir can be determined.

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