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PRODUCTION METHOD FOR STEEPLY-DIPPING FORMATIONS

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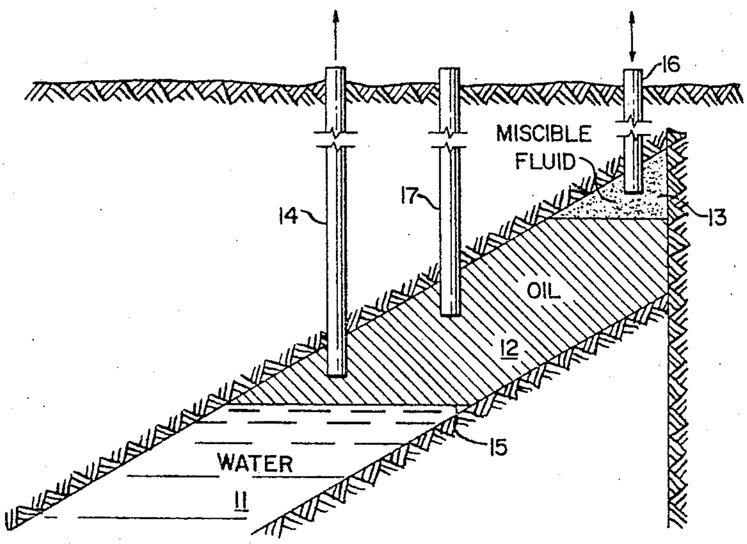

FIG. 1

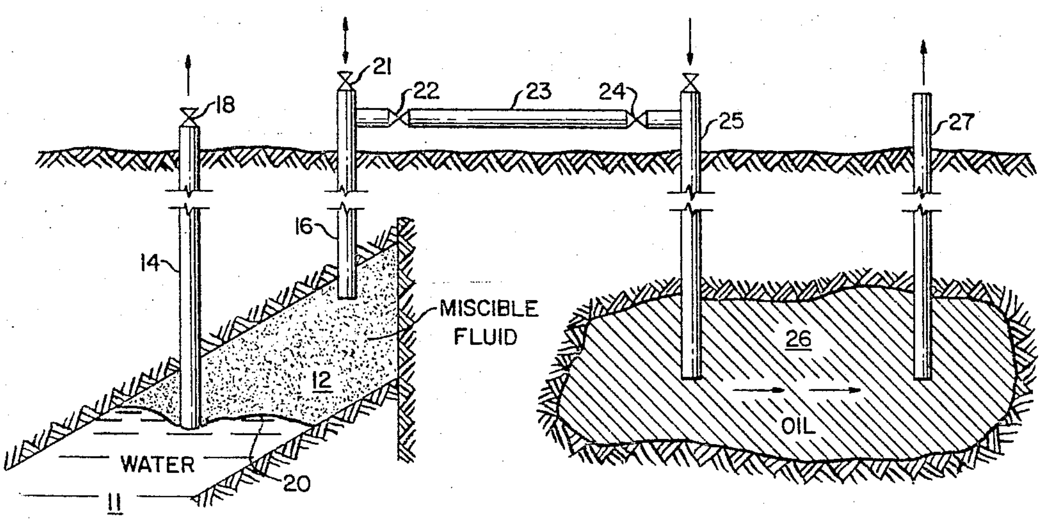

FIG. 2

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PRODUCTION METHOD FOR STEEPLY-DIPPING FORMATIONS

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This invention pertains to a method of recovering oil from steeply-dipping underground formations and pertains more particularly to increasing the oil recovery from steeply-dipping subterranean reservoirs of the water-drive type, that is, wherein a water-bearing formation under pressure exists below and in fluid communication with an oil bearing formation from which it is desired to produce oil.

Normally, steeply-dipping water-drive oil reservoirs are produced by drilling a well through the earth so as to communicate with the oil formation, preferably near the upper end thereof, and then opening the well to allow the water under pressure below the oil to pass up through the oil formation pushing the oil ahead of it and out the well until the entire oil-bearing formation has been flooded with water. In most cases a series of oil production wells are drilled into the oil formation to different levels and oil is produced from these wells with the wells being successively closed from the deepest well to the shallowest well as the oil-water interface moves up through the oil-bearing formation. The main drawback of producing a steeply-dipping water-drive reservoir in this manner is that from 20 to 30% residual oil may be left in the oil-bearing formation after it has been flooded with water from the water-bearing formation below.

It is therefore an object of the present invention to provide a method to produce a steeply-dipping water-drive oil reservoir in an efficient manner whereby all or substantially all of the oil may be produced from the oil-bearing formation prior to the time it becomes flooded with water.

Another object of the present invention is to provide a method for producing the major portion of oil from a steeply-dipping water-drive oil reservoir without allowing any substantial change in the position of the oil-water interface until substantially all of the oil has been produced.

These and other objects of this invention will be understood from the following description taken with regard to the drawing, wherein:

FIGURE 1 is a diagrammatic view illustrating, in longitudinal section, a steeply-dipping water-drive oil reservoir penetrated by a plurality of wells; and

FIGURE 2 is a diagrammatic view taken in longitudinal section of a steeply-dipping water-drive oil reservoir wherein the production well therefrom may be connected to the injection well of another oil field.

Wells drilled through a formation into a steeply-dipping reservoir may be classified as either up-dip wells or down-dip wells depending upon their relation to each other as to their termination point in the underground reservoir with which they communicate. Thus, in a steeply-dipping formation, a down-dip well would be one which terminated at a depth greater than an up-dip well.

In general, the method of the present invention comprises opening at least one down-dip well into fluid communication with the oil in the reservoir at the depth sub-

stantially as deep as that of the oil-water interface of the water-drive reservoir, opening at least one up-dip well into fluid communication with the reservoir at a significantly shallower depth, injecting a miscible fluid having a density not exceeding that of the oil through the up-dip well while producing oil through the down-dip well until the lower boundary of the injected fluid is moved downward approximately to the depth of the oil-water interface, and terminating the injection and subsequently producing the injected fluid from the up-dip well by permitting the water level to rise in the reservoir.

The above-described process can be advantageously utilized to produce another oil-bearing formation with a miscible fluid being discharged from the reservoir under water pressure by the above-described method. Thus, the miscible fluid could be led from the first reservoir into a second reservoir to drive the fluid therefrom.

Referring to FIGURE 1 of the drawing, a steeply-dipping reservoir is illustrated as having a water-producing zone 11 under pressure below an oil-bearing formation 12. A gas zone may or may not exist above the oil formation 12. In accordance with the present invention at least two wells are drilled through the earth from the surface and intersect and are in communication with the steeply-dipping water-drive reservoir. Preferably, a production well 14 is provided with its lower end terminating in the area generally above the oil-water interface normally existing in the formation. However, at times, as will be described hereinbelow, it may be desirable to have the production well 14 with its lower end in communication with the reservoir at a point slightly below the oil-water interface 15.

A second well, generally employed as an injection well, is provided in communication with the oil reservoir at a shallower depth in the reservoir than well 14. Preferably, the injection well 16 is in communictaion with the most shallow portion of the reservoir. If desired, a second production well 17 may be utilized.

In carrying out the method of the present invention in a steeply-dipping reservoir with the well arrangement shown in FIGURE 1, a miscible fluid of a density no greater than the oil is injected under pressure through injection well 16 so that the oil in the oil formation 12 is forced up the production well 14. The injection through well 16 is continued until all of the oil has been swept out of the oil formation 12 and up the production well 14 while the oil-water interface 15 remains substantially at the same level. Subsequently, the production well 14 is closed in any suitable manner while injection through well 16 is stopped. The former injection well 16 is then opened to act as a production well with the miscible fluid in the reservoir which was previously injected thereinto being forced from the reservoir as the water 11 is allowed to rise in the reservoir. By the time the water has risen to the lower end of the well 16, the majority of the miscible fluid in the oil reservoir has been swept out to the surface where it may be recovered or used in any other suitable manner as will be described hereinbelow.

In the arrangement shown in FIGURE 2, the method of the present invention has proceeded to the point where all of the oil has been swept out of the steeply-dipping formation by a miscible fluid injected through well 16 with the oil being produced out well 14. At this point well 14 is closed at the top thereof, as by a valve 18, and the water 11 is allowed to rise so that the interface 20 between the water and the miscible fluid is allowed to rise as the water pushes the miscible fluid through the reservoir and up the well 16. At the top of well 16 a valve 21 has been closed and a valve 22 opened so that the miscible fluid being produced from the reservoir flows up the well 16 through open valve 22 and through connecting pipe 23 and open valve 24 into an injection well 25 of an oil field located at some distance from the steeply-dipping reservoir, but in the vicinity thereof.

Thus, a miscible fluid drive may be carried out in the second oil-bearing reservoir 26 which, in addition to an injection well 25, is provided with at least one production well 27. It will be seen that oil-miscible fluid will be injected into the second reservoir 26 to effect a fluid drive oil production under an injection pressure augmented by the pressure of the water drive of the first reservoir, that is, the steeply-dipping reservoir.

The miscible drive fluid can be any gas or liquid that is miscible with the reservoir oil (that is, mixes with and forms a single phase solution) at the pressure and temperature at which it contacts the reservoir oil, while at the same time being less dense than the reservoir oil at such a pressure and temperature. The preferred miscible drive fluids comprise the light hydrocarbon solvents for crude oil, for example, residue gas for use in reservoirs having pressures high enough to cause the gas to be miscible, liquefiable petroleum gases (LPG) such as ethane, propane, butane etc., and/or their mixtures with each other or with residue gas for use in reservoirs having pressures low enough to require the drive gas to be enriched by liquefiable petroleum gases. The method of the present invention is also suitable when use is made of low-molecular weight alcohols, such as methyl, ethyl, propyl, etc., wherever it is desirable to use such a relatively expensive miscible drive fluid.

In a typical production system for a steeply-dipping reservoir, the reservoir pressure may be about 3,000 p.s.i. and the temperature 240° F. with the reservoir fluid composition comprising say about 65% methane, about 10% saturated hydrocarbons with from 2 to 6 carbon atoms and the remainder being saturated hydrocarbon material having 7 or more carbon atoms. For an injection fluid composition to drive this material from the reservoir, a 50–50 mixture of methane and propane could be employed which composition would be miscible when injected into the reservoir at the temperature and pressure thereof.

It is to be noted that when liquefied petroleum gases are employed, for example in the arrangement shown in FIGURE 1, after injection of the liquefied petroleum gases as the miscible fluid to drive the oil from the formation, the injection well 16 may be closed whereby the reservoir forms an underground storage system for the injected liquefied petroleum gases. These gases could be left in storage in the reservoir until the market situation was more favorable. Since the viscosity of liquefied petroleum gases is low, even the initial batch of stored liquefied petroleum gas would be recovered in a high proportion, relative to the proportion of the recovery of a moderately viscous crude oil, by natural water drive from the water formation 11. In addition, since a water drive consistently reduces the saturation of an oil phase liquid to a residual saturation that is mainly dependent upon the viscosity of the oil phase liquid, the recovery would be substantially complete with respect to additional batches of liquefied petroleum gases that are stored in the same manner. In storing additional batches, the liquefied petroleum gases would be injected through the up-dip wells while producing water from the down-dip wells. If it proved to be desirable, for example, to obtain a high rate of subsequent liquefied petroleum gas production, the produced water could be stored and then subsequently reinjected through the down-dip wells when it was desired to produce the liquefied petroleum gas from the reservoir. Alternatively, the fluid to be stored can be injected with the down-dip wells shut in so that the water level within the reservoir is forced downward by the inflow of the fluid to be stored.

In the system shown with regard to wells 14 and 16 in FIGURES 1 and 2, it is often difficult to obtain the final amounts of oil and/or solution of oil and miscible fluid from the oil reservoir 12 without withdrawing substantial amounts of the miscible fluid along with the liquid oil or oil-solution in the event that the miscible fluid is or contains a gas. Under these circumstances it is preferable to extend the lower end of the production well 14 into the water zone 11, as shown in FIGURE 2, so that a small amount of water will be produced along with the oil, rather than a large amount of gas. This is especially true in the stage of the process at which the oil comprises a relatively thin layer between the gas and the water in the same reservoir.

I claim as my invention:

1. A method of enhancing oil recovery from a gas-cap free water-drive oil reservoir having in one area an appreciable steep dip and containing an oil zone in communication with an underlying water zone under pressure, said method comprising the steps of

providing a production well from the surface in communication with the oil near the oil-water interface,

providing an injection well in communication with the oil reservoir at a shallower depth,

injecting through said injection well a miscible fluid of a density no greater than the oil while producing said oil through said production well,

continuing said injection of a miscible fluid until the lower boundary of the injected miscible fluid has moved downward to the general area of the oil-water interface while producing the oil through said production well,

terminating the injection of said miscible fluid and subsequently opening said injection well and producing said miscible fluid from said reservoir up said injection well to the surface by the water drive of the reservoir,

providing inlet and outlet wells in communication with a second oil reservoir,

connecting the injection well of the steeply-dipping reservoir with the inlet well of said second oil reservoir during the period said miscible fluid is produced from said injection well, and

injecting said oil-miscible fluid into the second oil reservoir through the inlet well thereof to effect a fluid drive of oil in said second oil reservoir under an injection pressure augmented by the pressure of the water drive in the steeply-dipping oil reservoir.

2. A method of enhancing oil recovery from a gas-cap free water-drive oil reservoir having in one area an appreciable steep dip and containing an oil zone in communication with an underlying water zone under pressure, said method comprising the steps of

providing a production well from the surface in communication with the oil near the oil-water interface,

providing an injection well in communication with the oil reservoir at a shallower depth,

injecting through said injection well a miscible fluid of a density no greater than the oil while producing said oil through said production well,

continuing said injection of a miscible fluid until the lower boundary of the injected miscible fluid has moved downward to the general area of the oil-water interface while producing the oil through said production well,

terminating the injection of said miscible fluid and subsequently opening said injection well and producing said miscible fluid from said reservoir up said injection well to the surface by the water drive of the reservoir, providing inlet and outlet wells in communication with a second oil reservoir,

connecting the injection well of the steeply-dipping reservoir with the inlet well of said second oil reservoir during the period said miscible fluid is produced from said injection well,

injecting said oil-miscible fluid into the second oil reservoir through the inlet well thereof to effect a fluid drive of oil in said second oil reservoir under an injection pressure augmented by the pressure of the water drive in the steeply-dipping oil reservoir, and

wherein gas is contained in said miscible fluid and the production well is provided with a draw-off inlet at a level below the normal oil-water interface thereby reducing the ratio of gas to oil being produced through said well while the last of the oil is being produced from said formation.

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