

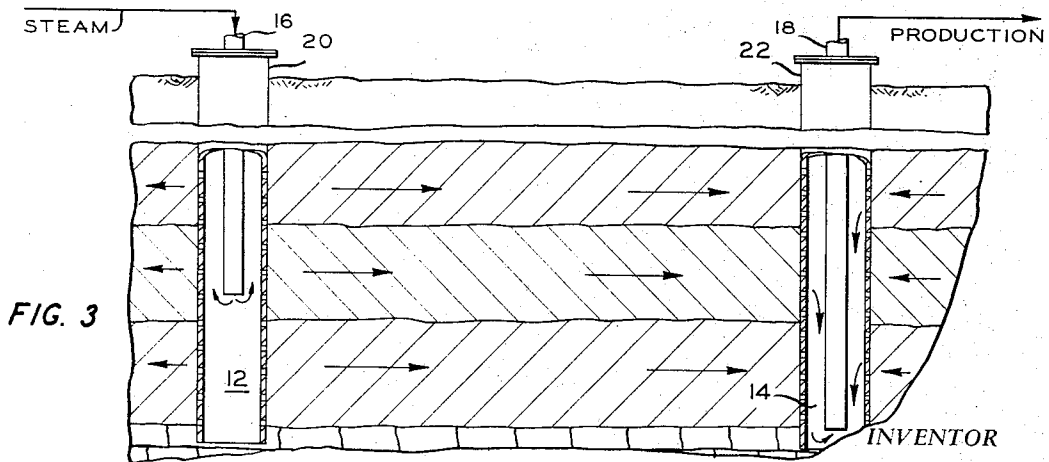
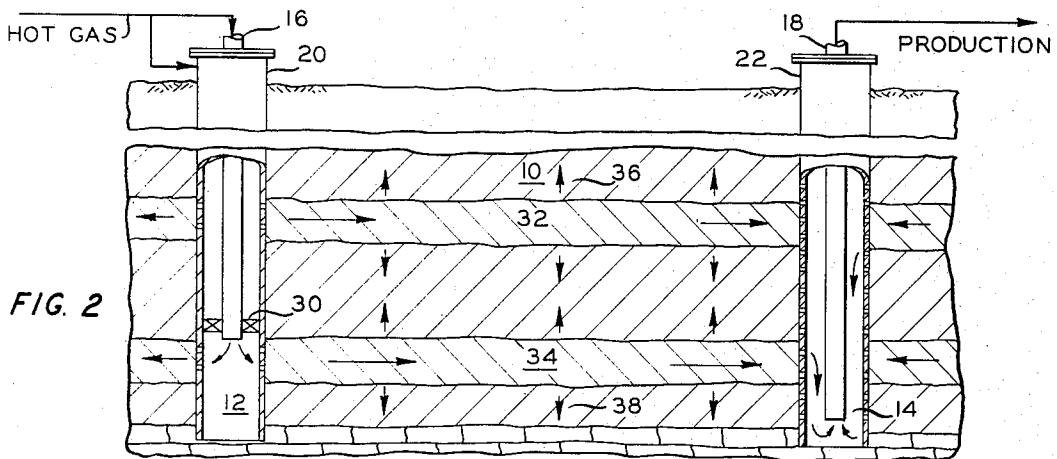
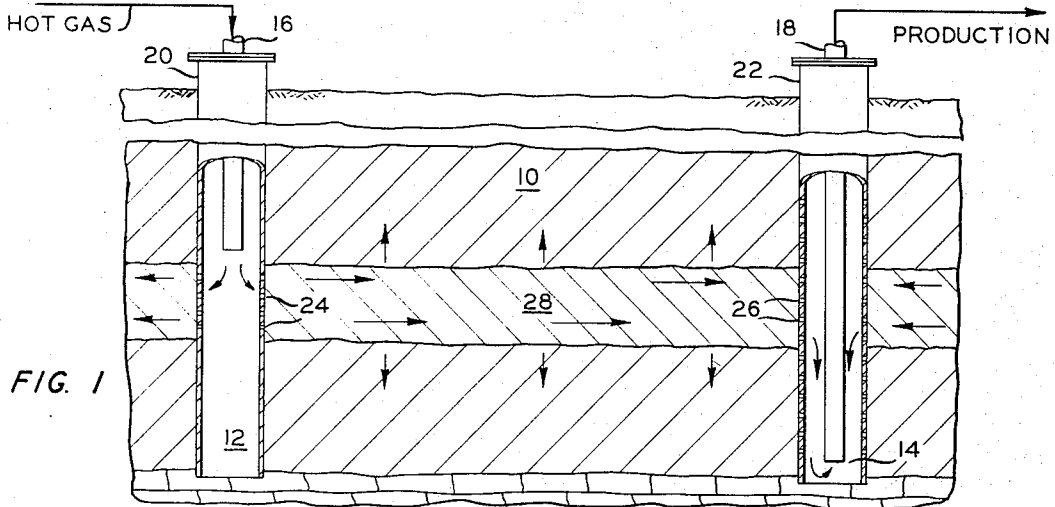
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RECOVERY OF HEAVY CRUDE OIL BY STEAM DRIVE

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RECOVERY OF HEAVY CRUDE OIL BY STEAM DRIVE

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This invention relates to a process for producing heavy crude oils from strata containing the same using hot fluid displacing agents.

Strata containing heavy crude oils, such as the Morichal field in Venezuela and certain fields in the United States, present difficult oil recovery problems, particularly when a direct steam drive is used in displacing the oil. The injection of steam and driving of the same into the stratum causes formation blocking by the heated oil and condensed steam (hot water) coming into contact with the colder formation oil radially more remote from the injection well. Crude oils having an API gravity below 20 and, particularly, below 15 are particularly troublesome in this respect and the invention herein is suitable for recovery of such crude oils.

This invention is concerned principally with a process which overcomes the problem of stratum blocking when applying steam injection in the recovery of heavy crude oil from a permeable stratum containing the same.

Accordingly, a principal object of the invention is to provide a process for effectively utilizing steam in the recovery of a heavy crude oil from a permeable stratum containing the same. Another object is to prevent stratum blocking when utilizing steam injection and steam drive in producing oil from a permeable stratum containing a heavy crude oil. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

A broad aspect of the invention as applied to a permeable stratum containing a heavy crude oil penetrated by an injection well and an offset production well comprises driving a hot non-aqueous gas thru a restricted substantially horizontal zone of the stratum lying between said wells at an intermediate level of the stratum so as to displace oil therefrom into the production well and open up the restricted zone to increased fluid flow, followed by injecting steam thru the injection well along substantially the entire face of the stratum and driving the steam toward the production well to displace additional oil thereinto, and recovering the produced oil from the production well. After a substantial period of steam injection ranging from several days to several months, it is preferred to follow the steam drive with a water flood drive. A suitable thickening agent, such as carboxy methyl cellulose, carboxy ethyl cellulose (or derivatives of these compounds), Dextran or polyox, etc., may be added to the aqueous driving fluid to enhance recovery. Dextran has the chemical formula $C_6H_{10}O_5$ and is further described by Rogers in Composition and Properties of Oil Well Drilling Fluids, revised edition, Gulf Publishing Company, Houston, Texas, 1953, page 426. Polyox is a poly(ethylene oxide) available from Union Carbide Corporation. The amount of thickening agent incorporated in the water flood is usually in the range of 0.1 to 2 weight percent and generally about 0.5 to 1 weight percent. The water flood may utilize water at atmospheric temperature or hot water, the latter being preferred.

In strata containing natural high permeability streaks, these can be readily detected in conventional manner and utilized as the restricted horizontal zone for injection of the hot non-aqueous gas. In such cases it is not necessary to case the injection well thru the stratum being produced since the injected gas naturally follows the streak of relatively high permeability. In most cases, however, the in-

jection well is cased thru the oil-bearing stratum and perforations are made in the casing at the selected level or levels at which the permeability of the stratum is to be increased. In application to strata of higher than average thickness such as 30 or 40' or more, two or more artificially created high permeability streaks are made at spaced-apart levels in the stratum to facilitate the transport of heat into the oil-bearing stratum.

A more complete understanding of the invention may be had by reference to the schematic drawing of which FIGURES 1, 2, and 3 are elevations thru a section of oil-bearing stratum penetrated by injection and production wells.

Referring to FIGURE 1, an oil-bearing stratum 10 is penetrated by an injection well 12 and a production well 14. Injection tubing 16 and production tubing 18 are provided in wells 12 and 14, respectively. Similarly, casings 20 and 22 extend into these respective wells. Casings 20 and 22 are perforated at a selected intermediate level of the stratum 10, such as that shown in perforations 24 and 26, respectively. Injected hot gas from tubing 16 enters stratum 10 thru perforations 24 and is forced thru the stratum to perforations 26, flushing oil from the intervening zone 28 of the stratum and opening this zone up to greater fluid flow. Zone 28 may vary in thickness, particularly, at the upstream end from about 1' to several feet, such as up to 10', in thickness. Usually this zone is limited to a range of 1 to 3', in thickness and is controlled by the spacing of perforation 24 in casing 20. Flow of the non-aqueous hot gas thru zone 28 produces oil which is recovered from tubing string 18 in conventional manner as by pumping, gas lift, or other means.

FIGURE 2 illustrates an arrangement of wells 12 and 14 in a thicker stratum 10 similar to that shown in FIGURE 1. Corresponding elements in FIGURE 2 are correspondingly numbered to those in FIGURE 1. The principal differences between the arrangement illustrated in FIGURE 2 and that in FIGURE 1 are in the thicker stratum and in the positioning of packer 30 in the annulus of well 12 between the tubing and the casing. Two zones 32 and 34 are open to flow from casing 20 to casing 22 thru perforations in the casings at the two selected levels and hot gas is injected both thru tubing string 16 and the surrounding annulus so as to drive the injected gas separately thru zones 34 and 10, respectively. In a stratum in which the permeability of one of zones 32 and 34 is lower than the permeability of the other zone, a higher pressure is applied to the injected hot gas entering the zone of lower permeability than the pressure on the gas entering the zone of higher permeability so as to more nearly approach simultaneous breakthrough of the injected gas into well 14. After breakthrough of the hot non-aqueous gas, perforations in casings 20 and 22 are extended along the entire face of the stratum 10 and steam injection is applied so as to continue the production of oil and heat substantially the entire stratum intermediate the injection and production wells. During the injection of hot non-aqueous gas, the stratum adjacent zones 32 and 34 is heated as indicated by arrows 36 and 38, the heat moving generally in a vertical direction from the heat zones within the stratum.

In FIGURE 3, corresponding elements are numbered to correspond with those in FIGURE 2 and this elevation illustrates the injection of steam over substantially the entire face of the stratum within well 12. In the arrangement shown steam is injected thru tubing string 16 after removing packer 30 (in FIGURE 2). It is also feasible to inject steam thru both the tubing string and the casing-tubing annulus, utilizing the arrangement illustrated in FIGURE 2 without removing packer 30, but after perforating casing 20 as required for an exposure of the entire face of the stratum to steam injection.

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During the early stages of steam injection zones 32 and 34 are much more permeable or open than the stratum above and below these zones; however, with continued steam flow, the adjacent stratum is continuously heated so as to render the oil therein much less viscous and more fluid, thereby causing this more fluid oil to flow into zones 32 and 34 from which the oil is flushed by the steam drive into production well 14 and recovered thru tubing 18. Eventually, the adjacent heated stratum is opened up sufficiently that steam penetrates the same and steam flow occurs substantially throughout the well pattern.

In operation with either the arrangement of FIGURE 1 or that of FIGURES 2 and 3, after steam drive for a period ranging from several days to several months or even a year or more, the steam drive is terminated and water is injected thru well 12 as the flooding and driving medium and additional oil is produced thru well 14. Generally, steam drive is continued until the stratum within the well pattern is heated substantially to a temperature approaching steam temperature which may be in the range of about 300 to about 600° F. or even higher. It is feasible to inject hot water as the final flooding medium but it is also feasible to inject flooding water at atmospheric temperature in view of the fact that the invading water is raised to the boiling temperature as it passes from the injection well into the hot surrounding stratum and additional steam is created in advance of the aqueous flood so as to further improve the recovery of oil. In this manner, the injection of flood water conserves and utilizes the heat already deposited in the stratum from the steam drive.

In any of the arrangements illustrated in the drawing, well 20 may be a central well in a ring pattern of wells 22 or it may be a well in a line of injection wells flanked on either side by lines of production wells 22. In other words, the invention is applicable to conventional well patterns utilized in the petroleum industry.

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 oil from a permeable stratum containing a heavy crude oil, said stratum being penetrated by an injection well and an offset production well, which comprises the steps of:

- (1) providing said injection well with a casing extending thru said stratum;
- (2) perforating said casing at at least one restricted intermediate level within said stratum;
- (3) injecting a hot non-aqueous gas thru said injection well and the perforations formed in step (2) and driving same thru said stratum to said production well so as to displace oil thereinto and open up said stratum along the path of said gas;

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(4) thereafter, perforating said casing above and below said intermediate level;

(5) driving steam into said stratum from said injection well thru the perforations formed in steps (2) and (4) so as to displace oil into said production well; and

(6) recovering from said production well the oil displaced by steps (3) and (5).

2. A process for producing oil from a permeable stratum containing a heavy crude oil, said stratum being penetrated by an injection well and an offset production well, which comprises the steps of:

(1) driving a hot non-aqueous gas thru a restricted substantially horizontal zone of said stratum at an intermediate level thereof so as to displace oil therefrom into said production well and open up same to increased fluid flow;

(2) thereafter, injecting steam thru said injecting well along substantially the entire face of said stratum and driving same toward said production well so as to displace additional oil into said production well; and

(3) recovering oil produced by steps (1) and (2) from said production well.

3. The process of claim 2 wherein said stratum is relatively thick and step (1) is effected at two different intermediate levels prior to step (2).

4. The process of claim 3 wherein the permeability at one of said levels is lower than at the other and injection pressure at the lower permeability level is higher than at the higher permeability level.

5. The process of claim 2 wherein said gas is hot combustion gas.

6. The process of claim 2 wherein step (2) is followed by a water flood drive to displace additional oil into said production well and additional oil recovery therefrom.

7. The process of claim 6 wherein a thickening agent is incorporated in the flood water.

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