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PREVENTION OF WATER INVASION INTO A HEAVY CRUDE RESERVOIR

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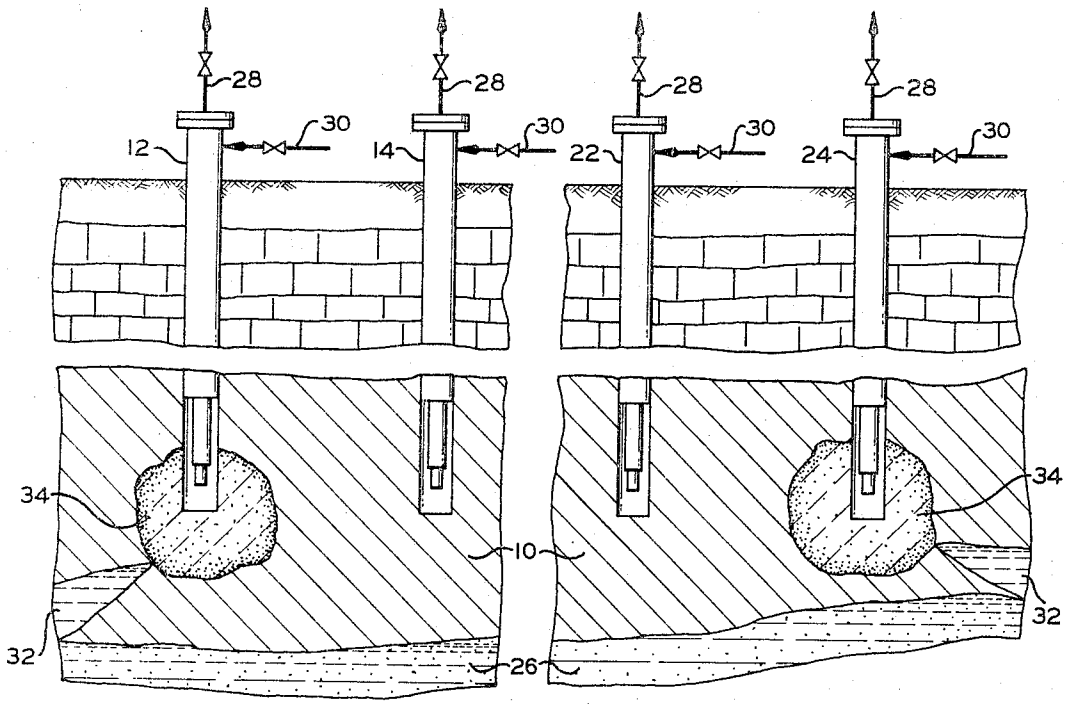


FIG. 1

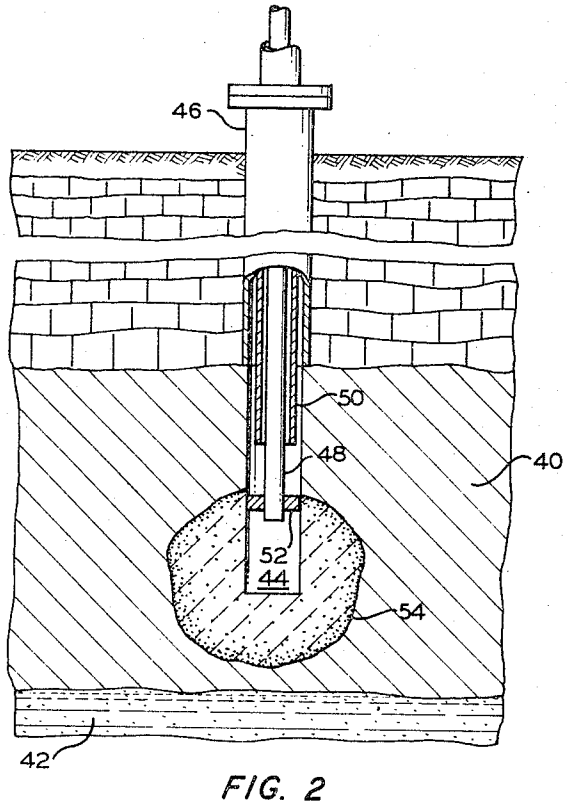


FIG. 2

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PREVENTION OF WATER INVASION INTO A HEAVY CRUDE RESERVOIR

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This invention relates to a process for preventing or reducing water encroachment on or in a stratum containing a relatively heavy crude oil from a water-containing stratum adjacent the oil stratum.

Water encroachment in low gravity oil reservoirs tends to be very irregular and this irregularity is caused by selective encroachment, water leg tonguing, and/or individual well coning. In the past, irregular encroachment has been impeded by gas injection or some method of water production from a well or wells in the affected reservoir. The production of water is intended to obtain a balance with the water influx from the aquifer. The problem involved may be water encroachment from the subjacent aquifer around the boundary of an oil field or reservoir. It may also be the invasion of water into a single well area under production, by water coning.

This invention is concerned with a method or process for retarding or preventing water invasion of a selected area of a stratum bearing heavy crude oil from an adjacent stratum bearing water.

Accordingly, it is an object of the invention to provide a process for preventing water invasion of an oil-bearing stratum from an adjacent stratum containing water. Another object is to prevent invasion of water from an aquifer around the edge of the oil-bearing stratum or reservoir. 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 an oil-bearing stratum adjacent an aquifer, the oil-bearing stratum being penetrated by a well, comprising passing a hot heating fluid thru the stratum adjacent the well outwardly therefrom so as to displace oil from a first section of the stratum and build up a liquid bank of the oil saturating an adjacent section of the stratum to form a viscous oil barrier intermediate the water-bearing stratum and the first section. This liquid barrier retards or prevents flow of water from the water-bearing stratum or aquifer into the oil-bearing stratum. As applied to an oil field or reservoir, the invention involves injecting the heating fluid thru wells adjacent the boundary of the field or reservoir so as to build up a liquid bank of heavy oil along and between the wells which provides a barrier to the influx or invasion of water. The invention is also applicable to the prevention or abatement of water invasion of a single well in a stratum containing heavy crude oil as by coning. In this situation, the lower end of the well is packed off in conventional manner as with a packer around a tubing string therein to provide a flow path for hot fluid to the lower section of the stratum adjacent the well. The hot fluid is then injected into the packed off section of the well and into the stratum to drive heavy crude deeper into the stratum and form the liquid bank of heavy oil required for the retardation or prevention of water coning or water invasion. The well is then produced from the section of the stratum above the packer by pumping or by other conventional means.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing of which FIGURE 1 is an elevation thru an oil field penetrated by a plurality of wells and FIGURE 2 is an elevation thru a single well penetrating a stratum containing a viscous crude oil overlying an aquifer.

Referring to FIGURE 1, a heavy viscous crude oil-bearing stratum **10** is penetrated by a plurality of wells **12**, **14**, **22**, and **24** representing spaced wells in an oil field. Wells **12** and **24** represent wells along the boundary or edge of the oil-bearing stratum **10**. Subjacent stratum **10** is aquifer **26** from which oil tends to invade the overlying oil stratum. Each well is provided with a tubing string **28** and a line **30** connecting with the well head for injection of hot fluids into the wells as needed. Injection thru the boundary wells may also be effected thru the tubing string.

A finger of water **32** illustrates the invasion of water into stratum **10** along the edge of the reservoir. In order to combat this water invasion, a hot heating fluid is injected thru wells **12** and **24** and other boundary wells where water invasion is a problem so as to drive the viscous oil away from the section of stratum immediately adjacent the lower end of the well. One method of accomplishing this result is to position a packer (not shown) around the lower end of tubing **28** and inject the hot fluid into the packed off section so as to drive the viscous oil outwardly therefrom and form a liquid bank of oil **34** which saturates the stratum in the area which it occupies, thereby reducing the effective permeability of this spherical "shell" of oil so as to form the required barrier to water invasion. During the formation of oil bank **34**, the other wells in the field inside the boundary wells are under normal production which may be intermittent or continuous.

The hot heating fluid may be steam, combustion gas, normally gaseous hydrocarbon, liquid hydrocarbons substantially lighter than the crude (including kerosene, diesel oil, gasoline, etc.), hot water, and other fluid materials which are nondeleterious in the reservoir. A preferred method of forming the liquid bank of oil comprises igniting the oil in the stratum adjacent the lower end of the well and driving a forward drive in situ combustion zone into the stratum until plugging results as indicated by the inability to inject further combustion-supporting gas under reasonable compressor pressure. The heavy crude oil is rendered less viscous during the heating and is driven deeper into the stratum where the temperature is lower than in the combustion area so that the heavy crude becomes considerably more viscous and even congeals in the cooler stratum, thus sealing off the stratum to invasion of water.

Steam is also an excellent heating fluid for injection and formation of a bank of heavy crude in the stratum as a barrier to water invasion. In the event water has already reached the boundary well, the injection of hot fluid drives the oil outwardly from the injection well and forces the invading water back toward the aquifer and also builds up the desired bank of heavy oil to obstruct the invasion of water. The injection of hot fluid is repeated as often as required to maintain the required liquid bank of heavy oil.

Referring to FIGURE 2 stratum **40** contains a heavy crude oil and overlies aquifer **42** from which water invasion as by coming around well **44** is a problem. Well **44** is provided with a casing string **46**, a first tubing string **48** and a second tubing string **50** which may be concentric therewith or positioned along side of same. A packer **52** is positioned around the lower end of tubing string **48** to pack of the lower end section of the well within stratum **40**. The same technique of operation is utilized around well **44** as previously described in connection with boundary wells **12** and **24** in FIGURE 1 so as to form a liquid bank of heavy oil **54** around the lower packed off section of the well. During formation of liquid bank **54**, well **44** is closed to production thru conduit **50** or other means. This prevents any substantial production of oil into the well

above packer 52. After the liquid bank has been formed to prevent water invasion from aquifer 42, the upper section of stratum 40 is produced in any conventional manner.

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.

We claim:

1. In an oil field penetrated by a plurality of spaced producing wells extending into an intermediate level of a stratum bearing low gravity viscous crude oil which overlies an aquifer and wherein water tends to invade said stratum along the boundary of said field, the method of combatting water invasion along said boundary comprising passing a hot heating fluid at a temperature substantially above in-place oil temperature into said stratum around wells adjacent the edge of said field so as to heat and drive viscous crude away from said wells where the heated crude cools to form a viscous liquid bank of said crude in the stratum around each well which saturates the stratum and reduces water invasion from the aquifer.

2. The method of claim 1 including producing wells in the field other than the boundary wells and intermittently injecting hot heating fluid into the boundary wells.

3. The method of claim 1 wherein said hot fluid is combustion gas.

4. The method of claim 1 wherein the heating gas is steam.

5. A process for producing a well penetrating to an intermediate level of a stratum bearing a viscous crude oil and overlying an aquifer, wherein water tends to invade said stratum adjacent the lower end of said well, which comprises the steps of:

(a) packing off the lower end section of said well around a tubing string therein to provide a separate flow path for a hot fluid;

(b) passing a hot fluid at a temperature substantially above in-place oil temperature into said stratum around the packed off section of said well so as to heat and displace viscous oil into a liquid bank in the surrounding stratum substantially completely surrounding the lower end of said well where the displaced oil cools and forms a viscous barrier to water invasion into the lower end of said well; and

(c) producing oil from the stratum above the level of the packed off section and above said liquid bank of oil.

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

7. The process of claim 5 wherein said hot fluid is steam.

8. A method of retarding water invasion from a water-bearing stratum into a viscous oil-bearing stratum penetrated by a well only to an intermediate level thereof which comprises passing a hot heating fluid at a temperature substantially above in-place oil temperatue thru the stratum adjacent said well outwardly and downwardly therefrom so as to heat and displace oil from a first section thereof and build up a liquid bank of said oil, saturating an adjacent section of said stratum completely surrounding the lower end of said well where said displaced oil cools to form a viscous oil barrier intermediate said water-bearing stratum and said first section, thereby retarding flow of water upwardly from said water-bearing stratum into said oil-bearing stratum.

9. The process of claim 8 wherein said hot fluid is combustion gas.

10. The process of claim 8 wherein oil in said stratum adjacent said well is ignited and combustion-supporting gas is fed to the ignited area of said stratum so as to move a combustion zone into the stratum radially outwardly from said well and hot products of the combustion serve as said hot fluid.

11. The process of claim 8 wherein the hot fluid is steam.

12. The process of claim 8 wherein said hot fluid is a hydrocarbon substantially lighter than said crude oil.

13. In an oil field penetrated by a plurality of spaced producing wells extending into a stratum bearing low gravity viscous crude oil which overlies an aquifer and wherein H_2O tends to invade said stratum along the boundary of said field, the method of combatting water invasion along said boundary comprising igniting the oil in said stratum around each boundary well and moving a combustion zone into said stratum from each well, thereby driving viscous crude oil away from said wells with the resulting hot combustion gases to an area relatively remote from said wells where the viscous crude cools and forms a viscous liquid bank saturating the stratum and reducing water invasion from the aquifer.

14. A process for producing a well penetrating a stratum bearing a viscous crude oil and overlying an aquifer, wherein water tends to invade said stratum adjacent the lower end of said well, which comprises the steps of:

(a) packing off the lower end section of said well around a tubing string therein to provide a separate flow path for a hot fluid;

(b) igniting said stratum around the packed off section of said well and driving a combustion zone into the surrounding stratum so as to heat and displace viscous oil into said surrounding area where said oil cools and forms a viscous barrier to water invasion into the lower end of the well; and

(c) producing oil from the stratum above the level of the packed off section and above said liquid bank of oil.

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