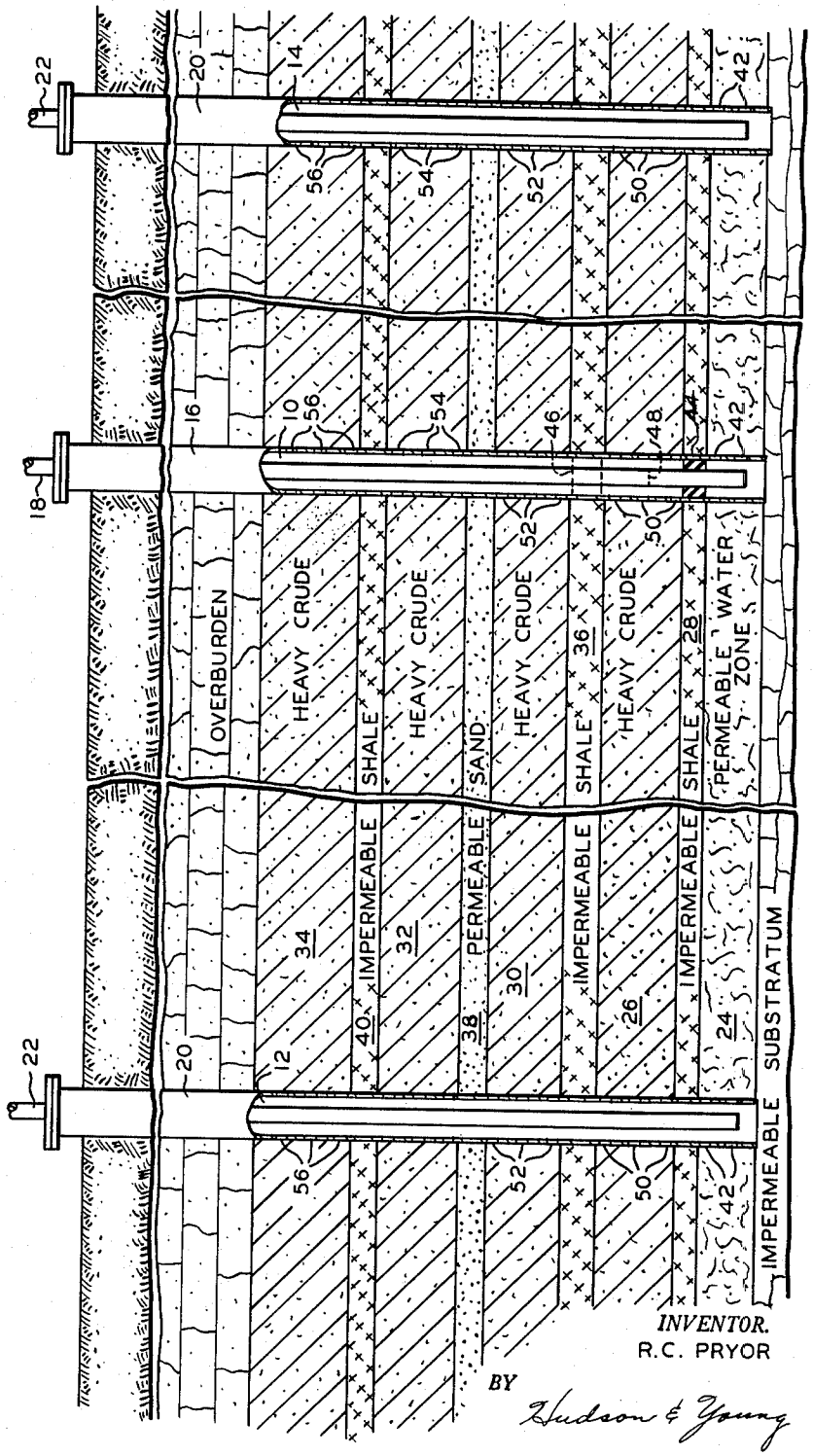
Jan. 26, 1965 R. C PRYOR 3,167,120

RECOVERY OF CRUDE PETROLEUM FROM PLURAL STRATA BY HOT FLUID DRIVE

Filed June 15, 1961



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United States Patent Office 3,167,120
Patented Jan. 26, 1965

3,167,120

RECOVERY OF CRUDE PETROLEUM FROM PLURAL STRATA BY HOT FLUID DRIVE

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Filed June 15, 1961, Ser. No. 117,347
11 Claims. (Cl. 166—10)

This invention relates to a process for producing oil from an oil-bearing subterranean stratum by fluid drive.

Heavy crudes or crudes of low A.P.I. gravity are particularly difficult to produce by ordinary or conventional methods of production. Monagas Venezuela crude is of this type. In the South Monagas field, the Oficina sands are composed of layers of sand (mostly unconsolidated or loosely consolidated) separated by relatively thin impermeable shale layers. Permeable water-bearing sands exist in both the upper and lower Oficina sections. The crude is so viscous that it is not readily amenable to conventional water flooding or fluid drive with reasonably spaced wells. This invention is concerned with a process for the production of crude oil from such an environment.

Accordingly, it is an object of the invention to provide an improved process for producing crudes of extremely low A.P.I. gravity. Another object is to provide an improved method of producing heavy crude by fluid drive. A further object is to eliminate pumping and the use of down-hole equipment involving moving parts. It is also an object of the invention to increase the recovery of crude in primary production in the production of crude. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises passing a hot fluid, such as superheated H_2O, thru a permeable stratum free of oil and lying adjacent a permeable oil-bearing stratum but separated therefrom by an impermeable barrier, so as to heat the oil-bearing stratum (and its oils) to an elevated temperature which greatly reduces the viscosity of the crude oil; and, while the crude oil is in heated condition, forcing a fluid flushing or displacing agent thru the oil-bearing stratum to force the oil into a production well from which it is produced in conventional manner. A preferred embodiment of the process utilizes superheated water or steam as the fluid for flooding the permeable stratum adjacent the oil-bearing stratum. The use of superheated water or steam as the oil-driving fluid is also preferred. By utilizing heated water at a temperature of about 540° F., Monagas crude is lowered in viscosity so that it has the viscosity of water used in the water drive. This preheating of the crude renders it readily producible by hot water or steam drive without resorting to extremely close well spacing. Hot gases such as air, combustion gases, etc., may be used to supply the heat for the first preheat.

In practicing the invention, the temperature of the preheating fluid used to flood the permeable oil-free stratum ranges from about 300 to 750° F., depending upon the character of the crude to be produced. The temperature of the preheated crude should be high enough to lower its viscosity to that of water. The pressure applied to the water or steam is dependent upon the temperature to be attained.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing which is an elevation in partial cross section of an arrangement of wells in a formation to which the invention is adapted.

Referring to the drawing, injection well **10** represents either a central injection well of a conventional 5, 7, or 9-spot well pattern, or an injection well in a line of injection wells. In the first case, wells **12** and **14** represent production wells in the ring; and in the second case, wells **12** and **14** represent wells in two lines of production wells parallel to and on each side of the line of injection wells **10**. Well **10** is provided with casing **16** and tubing **18**, while wells **12** and **14** are provided with casing **20** and tubing **22**. The wells extend thru a permeable water zone or stratum **24** lying adjacent a stratum **26** containing heavy crude and separated from stratum **24** by impermeable shale **28**. Strata **30**, **32**, and **34** also contain heavy crude and are separated by impermeable shale **36**, **38**, and **40**.

The casing **16** of injection well **10** is perforated at **42** and corresponding perforations are made in casing **20** of the production wells. Hot fluid such as superheated water or steam is injected thru tubing **18** so that it floods stratum **24** and drives out water therefrom into production wells **12** and **14**. The flooding of stratum **24** is continued for at least several cycles, one cycle being defined as the completion of flow of a body of flushing fluid from tubing **18** thru the stratum to tubing **22**. With normal well spacing, a flooding cycle extends over a period of at least a month. During an extensive period of several cycles, the adjacent oil-bearing stratum **26** is heated to a temperature approaching the temperature of the flooded stratum and is then ready for production by fluid drive or displacement.

During the injection of fluid thru stratum **24**, packer **44** around tubing **18** is utilized to confine the injected fluid to the desired section of well **10** adjacent perforations **42**. It is necessary to pack off the section of well **10** adjacent stratum **26** in order to produce this stratum. This is done by inserting packer **46** in casing **16** at the level of impermeable shale **36** and placing tubing **18** so that its lower end is at **48**, and either inserting an imperforate packer in lieu of packer **44** or plugging perforations **42**. Perforations **50** are produced in casing **16** and in casing **20**. Hot flushing fluid, preferably, superheated water at a temperature of at least 500° F., or superheated steam, is injected thru tubing **18** and into heavy crude-bearing stratum **26** while in preheated condition and the crude flows into wells **20** from which it is produced thru tubing **22** by the pressure of the injected hot fluid.

Shale zone **36** separating oil bearing strata **26** and **30** is relatively thin and heat is transmitted therethru during the production of stratum **26**, thereby heating the crude in stratum **30**. In order to provide adequate preheating of crude in stratum **30**, the injection of flushing fluid thru stratum **26** may be continued for several cycles. After adequately preheating stratum **30**, the sections of casings **16** and **20** adjacent this stratum are packed off in a manner similar to the packing off of the section of well adjacent stratum **26**, and casings **16** and **20** are perforated at **52** to provide a complete passageway for the injected and produced fluids.

Strata **32** and **34** are produced successively in the same or similar manner to the production of crude from strata **26** and **30**. This necessitates perforation of the casings at **54** and **56** as shown in the drawing. It is desirable to pack off the section of wells **12** and **14** being flooded and produced, in the same manner as well **10**, although this is not absolutely essential.

In the South Monagas field of Venezuela, the permeable water zone **24** is about 10 feet in thickness and has a porosity of about 30%. Utilizing a 57-acre well spacing and a 5-spot well pattern, the injection of 25,000 barrels per day (B.P.D.) of water superheated to 540° F. thru the center well is continued thru 6 cycles covering a period of about one year. The adjacent oil-bearing stratum (stratum **26**) of about 20 to 30 feet in thickness is preheated during this period to a temperature just below the injection temperature. As the temperature of the

crude in stratum **26** rises during the preheating period, oil begins to flow into the production wells thru perforations **50** and is produced along with the water or steam during the preheating period. The injected water forms a "pancake" of hot water surrounding the injection well and lying under the oil-bearing stratum to be preheated.

At the end of 6 cycles of injecting superheated water, injection is shifted to the preheated oil sand **26** and is maintained at the same rate of 25,000 B.P.D. and substantially at the temperature of 540° F. previously utilized.. At this rate of injection into the 20 to 30 foot thickness of oil stratum, only 2 or 3 cycles per year of circulation are effected. During the second year the hot water flushing produces between 70 and 80 percent of the oil in the stratum being produced.

During the production of oil from stratum **26**, heat is transferred thru impermeable shale **36** into oil sand **30** so as to raise the temperature of the heavy crude therein. In the event the crude in the upper area of stratum **30** is not raised sufficiently in temperature to render it easily producible by hot water flushing or steam flushing at the end of the second year with 2 to 3 cycles of circulation thru stratum **26**, injection of superheated water is continued for additional cycles until the desired amount of preheating is effected in stratum **30**. Stratum **30** is produced by the same method as applied to stratum **26** when a desirable temperature has been reached therein. In this manner, additional strata are preheated and produced in succession until all of the oil-bearing strata in the structure are produced.

It is to be understood that sections of wells **12** and **14** may be packed off adjacent the stratum being produced as illustrated in connection with injection well **10**. The injection pressure and the hydrostatic head in the injection well produce substantially all of the oil in liquid form thru tubing **22** without the aid of pumping equipment. This eliminates the use of downhole pumps and is a distinct advantage in producing the formation illustrated.

The invention permits production of a 57 acre tract in the Monagas field with only 5 wells, whereas original production methods therein required 16 wells on this size tract and produced 10 to 20 percent of the crude as contrasted with 70–80 percent produced by the process of the invention. Initial investment for the instant process is only about one-half of that required for producing by conventional methods. Actual acreage required for producing 12,000 B.P.D. of crude is reduced from 912 acres to 57 acres. Fuel for heating the water for the process is provided from the gas and waste oil-water emulsion from the process.

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. A process for producing hydrocarbons from a first permeable oil-bearing stratum, containing a viscous crude difficult to produce by fluid drive, which lies adjacent a second permeable stratum free of hydrocarbon material but separated therefrom by an impermeable barrier, said first and second permeable strata being penetrated by an injection well and by a production well, which comprises flooding said second permeable stratum with hot H_2O by injecting same thru one of said side wells into said second stratum and producing said H_2O thru the other of said wells, thereby preheating the adjacent first oil-bearing stratum; thereafter, while said first oil-bearing stratum is in preheated condition, injecting a hot fluid flushing agent under non-combustion conditions thru said injection well into the preheated stratum so as to drive oil therefrom into said production well, and recovering the produced oil from said production well.

2. The process of claim 1 wherein superheated hot water is injected as said H_2O to preheat said oil-bearing stratum and as said flushing agent.

3. The process of claim 1 using superheated steam as the flooding and flushing agents.

4. The process of claim 1 wherein a third permeable oil-bearing stratum lying adjacent said first oil-bearing stratum, but separated therefrom by an impermeable barrier, is preheated by the injected hot flushing agent, and said third stratum is produced while in preheated condition by injecting hot flushing agent into same thru said injection well and forcing same and heated oil therein toward said production well.

5. The process of claim 4 using superheated water as the flooding agent and as the flushing agent.

6. The process of claim 4 using superheated steam as the flooding agent and as the flushing agent.

7. The proceess of claim 1 wherein the injection temperature of said H_2O is at least 300° F. and said oil is a heavy crude.

8. The process of claim 1 wherein water superheated under pressure to a temperature of at least 500° F. is injected as the flooding agent and as the flushing agent.

9. The process of claim 1 wherein the flooding is continued for at least several cycles with H_2O at a temperature of at least 500° F. before flushing agent is injected into said first stratum.

10. The process of claim 9 wherein said flushing agent is also hot water injected at a temperature of at least 500° F.

11. The process of claim 1 wherein the flooding is continued for at least several cycles with hot H_2O before injecting said flushing agent; a third permeable-oil-bearing stratum lies adjacent said first permeable oil-bearing stratum and is penetrated by said wells; at least several cycles of hot H_2O flushing agent are applied to said first oil-bearing stratum to produce same and to preheat said third oil-bearing stratum; and said third oil-bearing stratum is produced while in preheated condition by injecting hot H_2O into same thru said injection well and driving same toward said production well.

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