

March 12, 1968

A. SATTER ETAL

3,372,750

RECOVERY OF HEAVY OIL BY STEAM INJECTION

Filed Nov. 19, 1965

5 Sheets-Sheet 1

OIL PRODUCING
AND STEAM
INJECTION WELL

WATER
WELL

12

12

2 8

Fig. 1

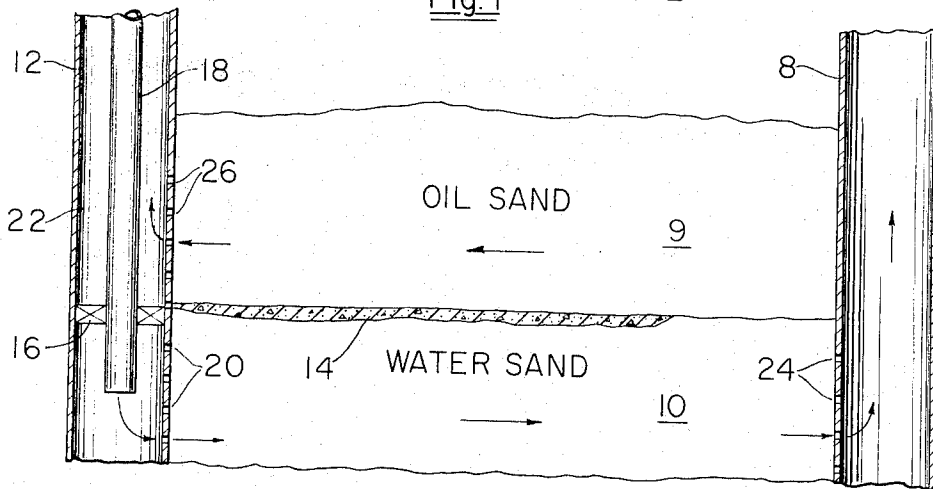


Fig. 2

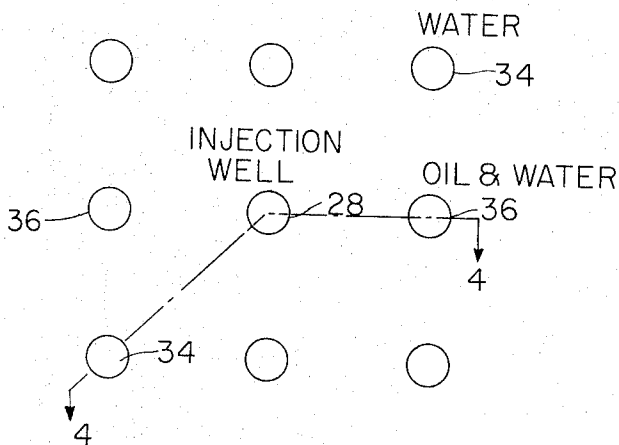


Fig. 3

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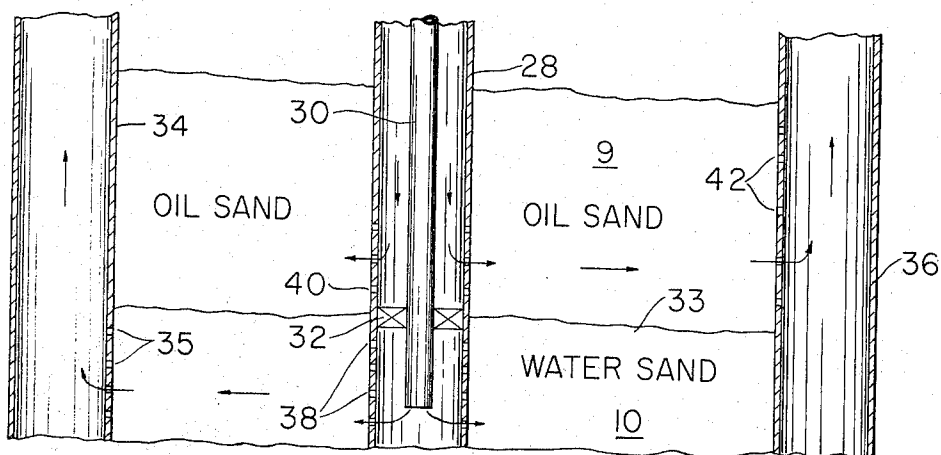


Fig. 4

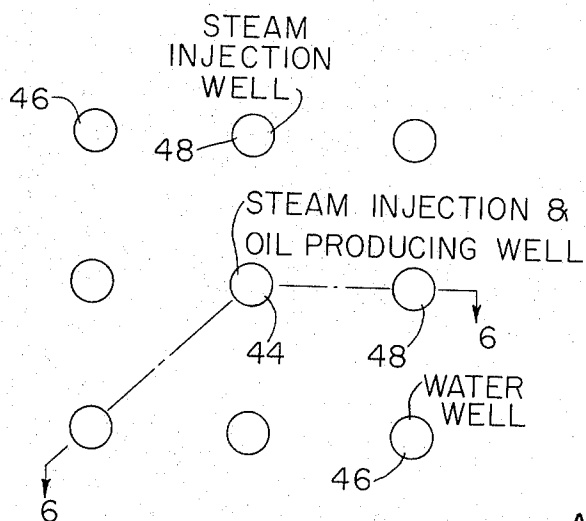


Fig. 5

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5 Sheets-Sheet 3

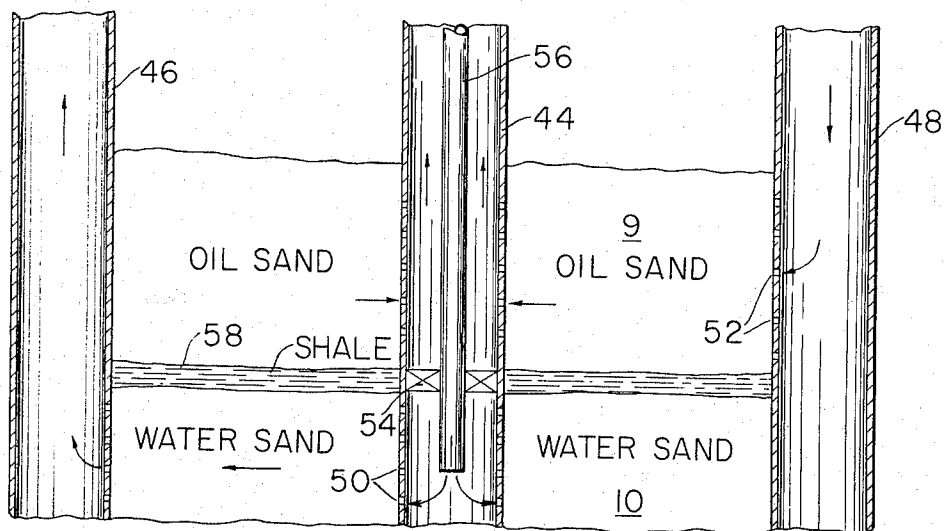


Fig. 6

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5 Sheets-Sheet 4

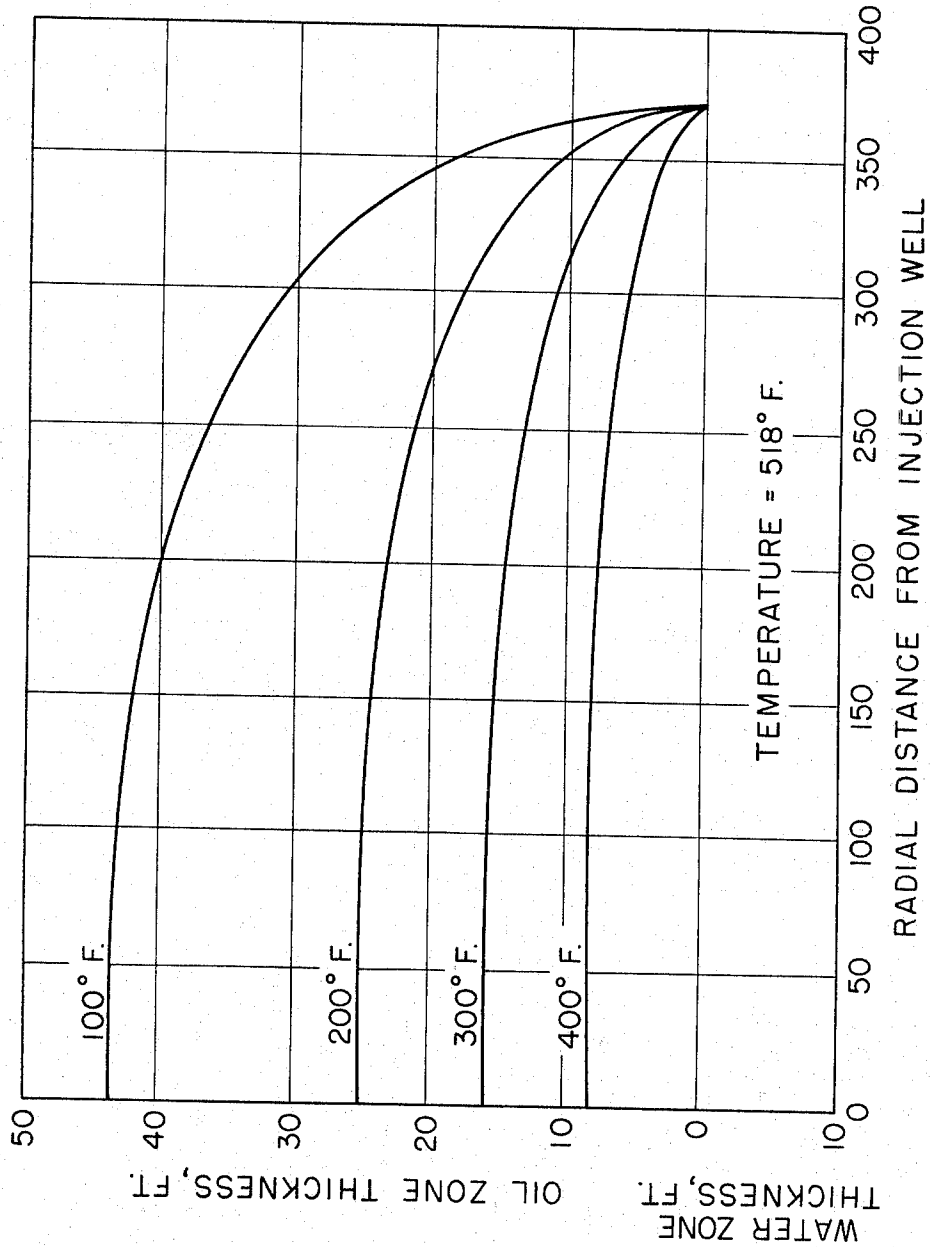


Fig. 7

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5 Sheets-Sheet 5

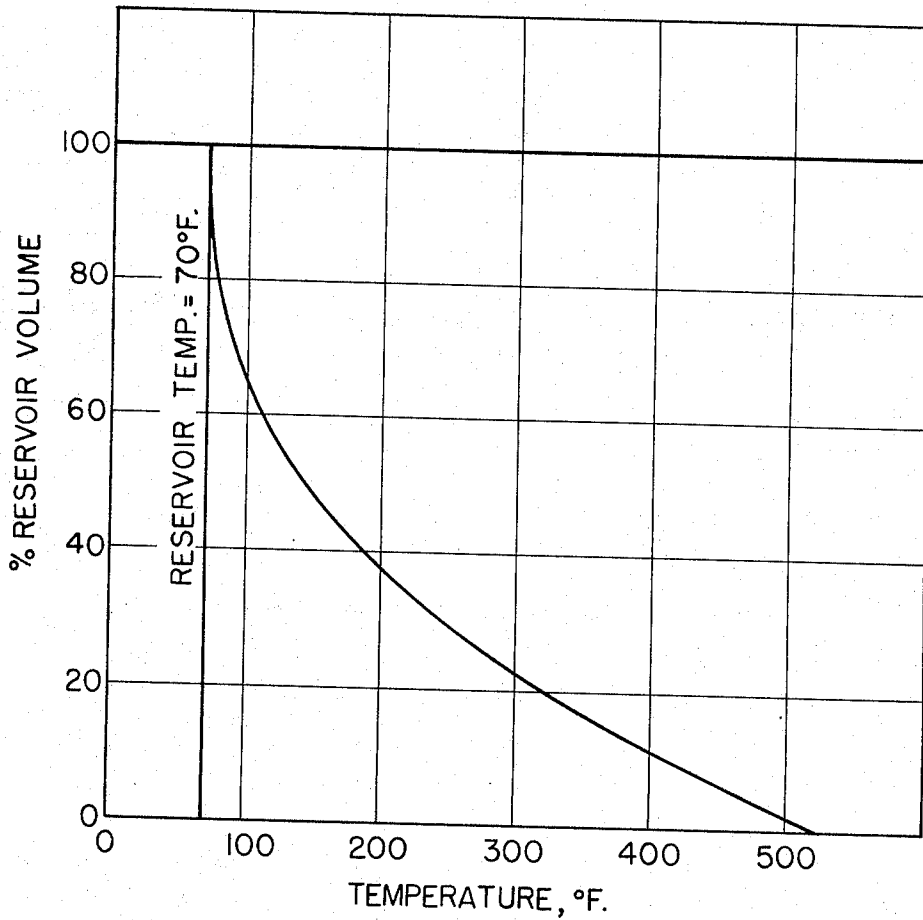


Fig. 8

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RECOVERY OF HEAVY OIL BY STEAM INJECTION

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5 Claims. (Cl. 166—11)

ABSTRACT OF THE DISCLOSURE

Steam is injected into an aquifer underlying a heavy oil reservoir to heat the reservoir and increase production, primarily by decreasing viscosity. A single steam injection-oil production well may be used along with a number of surrounding water-producing wells, or there may be a well-to-well displacement with one steam injection well, a set of surrounding water-producing wells, and another set of surrounding oil-producing wells, the two sets being respectively at the corners of the five-spot and at the midpoint of the border lines.

The present invention relates to the recovery of petroleum from underground deposits thereof by means of fluid drive. More particularly, it is concerned with, but not limited to, the recovery of petroleum having an API gravity of not more than about 25 degrees, i.e., hereinafter referred to as heavy oil, by steam injection under circumstances such that the steam not only serves as a drive agent to force oil into the producing well but to lower the viscosity of the oil over a substantial portion thereof, thus aiding in increased production over a shortened period of time.

In many areas of the world large deposits of petroleum exist which, because of their relatively low gravity, either cannot be produced or can only be produced inefficiently by conventional methods. Such deposits include the Athabasca tar sands in Canada, low gravity crudes in the Jobo Field in Venezuela, and similar crudes in Western Missouri, Eastern Kansas and Southern Oklahoma. Numerous proposals have been advanced for recovering petroleum of the type contemplated herein, some of which have involved steam injection, in-place combustion, etc., but none of them have met with unqualified success. For example, in the case of steam injection procedures, a period of months is often required in order to heat up a sufficiently large body of the oil before the accompanying reduction in viscosity can be exploited. Also, in the now well-known huff-and-puff process for recovering petroleum in which steam is injected into a well for a period of time after which the steam-saturated formation is allowed to soak for an additional interval prior to placing the well on production, much time elapses during which no production is obtained. Also, the relative permeability of the formation to oil decreases owing to the increase in water saturation.

It is therefore an object of our invention to provide a process by which heat can be applied to a large volume of the oil to be recovered while steam is simultaneously used to force the oil of reduced viscosity to the well. It is a particular object of our invention to provide a method for recovering heavy oil from a formation adjacent a water sand in which the oil and water are separated for a distance of at least 30 to 50 feet from the well bore by a natural or artificial, substantially fluid-impermeable barrier. It is another object of our invention to recover heavy oil from a formation having a water zone above and/or below the oil producing zone, simultaneously injecting steam or hot water into the oil and water zones,

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and separately recovering oil and water from two or more wells.

In the accompanying drawings,

FIGURE 1 is a diagrammatic representation of one embodiment of our invention having the wells arranged in a 5-spot pattern, the oil and water zones penetrated by each steam injection well being separated by an artificial barrier.

FIGURE 2 represents a segment taken along line 2—2 of the pattern shown in FIGURE 1.

FIGURE 3 is another illustration showing a 9-spot arrangement having a central steam injection well and water and oil producing wells at the corners and sides, respectively.

FIGURE 4 represents a segment taken along line 4—4 of the pattern shown in FIGURE 3.

FIGURE 5 illustrates still another arrangement of steam injection, oil and water producing wells.

FIGURE 6 represents a segment of the pattern shown in FIGURE 5 taken along line 6—6.

FIGURE 7 is a plot showing the temperature distribution in an oil-bearing formation—after 349 days' steam injection—due to conduction heating from water sand 10.

FIGURE 8 is another plot illustrating the percent of the oil reservoir subjected to elevated temperature when the process of our invention is used.

In carrying out an embodiment of our invention, and referring first to FIGURES 1 and 2, we have the wells arranged in a 5-spot pattern with the central well 8 producing water and steam condensate from aquifer or water sand 10. Wells 12, stationed at each corner of the 5-spot, serve the dual purpose of steam injection and oil producing wells. Initially, the formation is fractured as nearly as possible between oil sand 9 and water sand 10 after which cement is squeezed into the resulting opening to form a pancake or barrier 14 extending a substantial distance, i.e., for at least 50 feet between wells 8 and 12. Thereafter packer 16 carried on well tubing 18 is set opposite the cement-filled fracture so that tubing 18 communicates only with water sand 10 via the perforations 20 in casing 22. Steam is next introduced into water sand 10 via tubing 18 and by condensing, transmits heat by conduction through concrete barrier 14 to reduce the viscosity of the oil in sand 9. Water in sand 10, together with condensate, is removed from cased well 8 via perforations 24. Energy transmitted to oil sand 9, through bypassing a portion of the injected steam around the end of barrier 14, plus gravity drainage resulting from reduction in viscosity of the heavy oil, provide sufficient force to cause oil to flow into well 12 through perforations 26. Thus it is seen that energy required to cause oil to flow into well 12 is not only derived from gravity drainage resulting from a reduction of oil viscosity but is also supplied through the use of steam displacement. In this way predominantly water-free oil is produced continuously and substantially immediately from well 12, unlike the huff-and-puff steam injection operation now widely employed. An increase of rate of oil production is also obtained as the radius of the heat bank in oil-bearing sand 9 increases from the expansion of the steam zone in water sand 10. This method is versatile because it provides its own barrier between the oil and water sands and does not necessarily require the existence of a natural obstruction between the two sands.

After steam breakthrough occurs at water well 8, the rate of heat dissipation (due to conduction) from the steam-out water sand 10 into the oil-bearing sand 9 decreases with the injection time since the thermal gradient around the water sand decreases with time. If steam is injected at the original rate, the quality of steam produced increases with time and unnecessary loss of the injected

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heat results. We, therefore, propose that the steam injection rate be reduced with time, making sure that hot water essentially at the injected steam temperature be produced. Whether or not steam injection into the water-bearing formation should be continued or discontinued depends primarily upon the injection rate, well spacing, and the thickness of the oil zone.

Temperatures and steam pressures employed may vary widely. However, oil sand injection temperatures usually are greater than those employed for treatment of the adjacent water sand. Although the temperature and the quantity of steam suitable for a given reservoir depends to some extent on the formation temperature and pressure, formation break-down pressure of the reservoir, and well spacing, we generally prefer to employ water sand steam injection rates of from about 3000 to about 40,000 lbs./hr. at temperatures of from about 300° to about 700° F. For the oil sand steam injection, rates should ordinarily be somewhat lower than those used for treatment of water sands. As a general rule, the steam pressure should exceed the formation pressure in either the oil or water sand by from about 50 to about 1000 p.s.i.—but should not exceed the formation break-down pressure.

Referring again to the drawings, in FIGURES 3 and 4 we have a group of wells arranged in a 9-spot pattern with injection well 28 located in the center and equipped with tubing 30 and packer 32, set substantially at the oil-water interface 33. Cased corner wells 34 produce water from sand 10 through perforations 35 while cased side wells 36 produce oil and water from oil sand 9. It is apparent in this connection that the function of wells 34 and 36 may be reversed, if desired. Steam is injected into water sand 10 through tubing 30 and perforations 38 and into oil sand 9 through the well annulus and perforations 40. Water and condensate in sand 10 are produced from the various corner wells 34 while oil plus some condensate are produced from sand 9 via perforations 42 and side wells 36. Since a relatively thin section of water sand 10 is used to inject steam at a many fold higher rate than that used in injecting steam in oil sand 9, the water sand is steamed out much faster than the oil sand. This is also accentuated by the fact that the oil sand generally is much thicker than the water sand involved. After steam breakthrough occurs at water wells 34, steam injection into the water sand may be discontinued or the injection rate reduced as discussed before. If steam injection into water sand 10 is discontinued, the surrounding water wells 34 may, if desired, be perforated and converted into oil producers.

Thus by following the procedure described immediately above in connection with FIGURES 3 and 4, a major portion of the reservoir oil can be heated to a higher temperature in a much shorter time so as to reduce its viscosity materially. Production of oil into wells 36 is considerably enhanced by simultaneous steam displacement in oil sand 9. In a straight oil displacement process (through the oil sand without the simultaneous introduction of steam into an aquifer), the steam can be moved through the oil sand only a relatively short distance from the injection well. Although the temperature of the steam zone is essentially the same as that of the injected steam itself, the major portion of the oil reservoir ahead of the steam zone remains substantially at the original reservoir temperature if steam injection into the aquifer is not used in accordance with our invention. Thus, the present invention makes possible the production of oil at a higher rate much sooner than can be accomplished by conventional well-to-well steam displacement processes or methods which first inject steam into an aquifer adjacent the oil zone to reduce the oil viscosity and thereafter produce the oil by steam displacement.

In the case of the embodiment illustrated in FIGURES 5 and 6, another 9-spot pattern is employed with central well 44 being a combination steam injection and oil producing well. Corner wells 46 are water producers while side wells 48 are steam injection wells. It is con-

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templated that the function of cased wells 46 and 48 may be reversed. Prior to injection, steam via wells 44 and 48 and perforations 50 and 52, respectively; packer 54 carried on well tubing 56, is set substantially opposite naturally occurring fluid impermeable barrier 58, e.g., from about 5 to 10 feet in thickness, which may be shale or other equivalent material. Steam is then substantially simultaneously injected into oil sand 9 and water sand 10 through wells 48 and 44, respectively. As the result of the wide and substantial distribution of heat from water sand 10 through barrier 58, the oil in sand 9 is reduced in viscosity and is driven toward oil producing well 44 by energy supplied not only through gravity drainage but from steam displacement through the oil sand and via well 48. Recovery of oil flowing into well 44 is effected through flow up the annulus thereof. After steam breakthrough occurs at water wells 46, steam injection into the water sand may be discontinued or the injection rate reduced as discussed before.

The method of our invention will be further illustrated by reference to the following example:

Example

In a 5-spot pattern similar to that shown in FIGURE 1, wells are drilled through a 50-ft. oil-bearing zone and a 10-ft. thick water sand adjacent and directly beneath the oil-bearing zone. The reservoir has an initial temperature and pressure of 70° F. and 650 p.s.i.g. Eighty percent quality steam is injected into the water zone through the corner wells at a rate of 25,000 lbs./hr. at 800 p.s.i.a. and 518° F. Considering a radial flow and a drainage area of 10 acres, approximately 349 days are required to steam out the water-bearing zone. FIGURE 7 of the drawings illustrates the temperature distribution—by conduction of heat from the water zone—in the oil-bearing formation at the end of the 349-day steam injection period. FIGURE 8 shows the percent of the oil reservoir (by volume) which is subjected to the elevated temperatures. A considerable portion of the reservoir is heated to higher temperatures, for example, 37 percent of the volume of the reservoir attains the temperature of 200° F.—an increase of 130° F. from the original temperature. It should be also noted that a rise of 100 to 200° F. in reservoir temperature reduces the viscosity of heavy oil—at the original reservoir temperature—by a factor of 50 to several hundredfold.

As evident in the above illustration, at the time of steam breakthrough at the producing wells, a substantial part of the reservoir in the upper region of the oil-bearing formation may not be heated sufficiently, or any at all, to be responsive to the proposed method of oil recovery. In order to heat the cooler portion of the reservoir, steam injection into the water-bearing formation should be continued until a desired level of temperature rise, e.g., 50° F. or above, in the entire oil-bearing formation is achieved. If the injection rate is higher and/or the well spacing shorter than in the above example, the steam breakthrough time may be shorter and the steam injection time after steam breakthrough may be longer. Again, if the pay is thicker than, for example, 50 ft., longer time of steam injection may be required after steam breakthrough than is necessary in the case of the above example.

From the foregoing description it is apparent that we have provided the art with a novel, practical, and efficient method for recovering petroleum, particularly that of the low-gravity type defined above. By employing the method of our invention, oil recovery response is immediate as opposed to prior procedures requiring several months of heating before such oil is obtained. Moreover, the process of our invention may be employed in the presence or absence of a natural or artificial barrier between the aquifer and the oil-bearing stratum. Also, by the use of our invention one can employ simultaneously, to best advantage for oil production, the combined forces of gravity drainage and steam displacement which we have shown to constitute a material improvement over the use of these two forces in sequence.

We claim:

1. In a process for recovering petroleum from an underground deposit thereof penetrated by two wells, said deposit being adjacent a water-bearing zone, the improvement which comprises injecting steam down a first confined path in the first of said wells and into said water zone thereby heating and reducing the viscosity of the petroleum in said deposit, simultaneously injecting steam down a first confined path in the second of said wells and into said deposit, removing water from said zone through a second confined path in the second of said wells and recovering petroleum from said deposit through a second confined path in the first of said wells.

2. The method of claim 1 in which steam injection is continued after breakthrough into the second of said wells until the temperature rise in substantially the entire oil-bearing formation is at least 50° F.

3. In a process for recovering petroleum from an underground deposit thereof penetrated by three wells, said deposit being adjacent a water-bearing zone, the improvement which comprises injecting steam down a first confined path of the first of said wells and into said water bearing zone thereby heating and reducing the viscosity of the petroleum in said deposit, simultaneously injecting steam down the second of said wells and into said deposit, removing water from said zone via the third of said wells and recovering petroleum from said deposit through a second confined path in said first well.

4. In a process for recovering petroleum from an underground deposit thereof penetrated by two wells, said deposit being adjacent a water-bearing zone, the improve-

ment which comprises injecting steam down a first confined path in the first of said wells and into said water zone thereby heating and reducing the viscosity of the petroleum in said deposit, simultaneously injecting steam down a second confined path in said first well and then into said deposit, removing water from said zone via a first confined path in said second well and recovering petroleum from said deposit via a second confined path in said second well.

5. In a process for recovering petroleum from an underground deposit thereof penetrated by three wells, said deposit being adjacent a water-bearing zone, the improvement which comprises injecting steam down a first confined path of the first of said wells and into said water bearing zone thereby heating and reducing the viscosity of the petroleum in said deposit, simultaneously injecting steam down a second confined path in said first well and into said deposit, removing water from said zone via the second of said wells, and recovering petroleum from said deposit through the third of said wells.

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