

March 4, 1969

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RECOVERY OF PETROLEUM BY THERMAL METHODS INVOLVING TRANSFER OF
HEAT FROM ONE SECTION OF AN OIL-BEARING FORMATION TO ANOTHER

3,430,700

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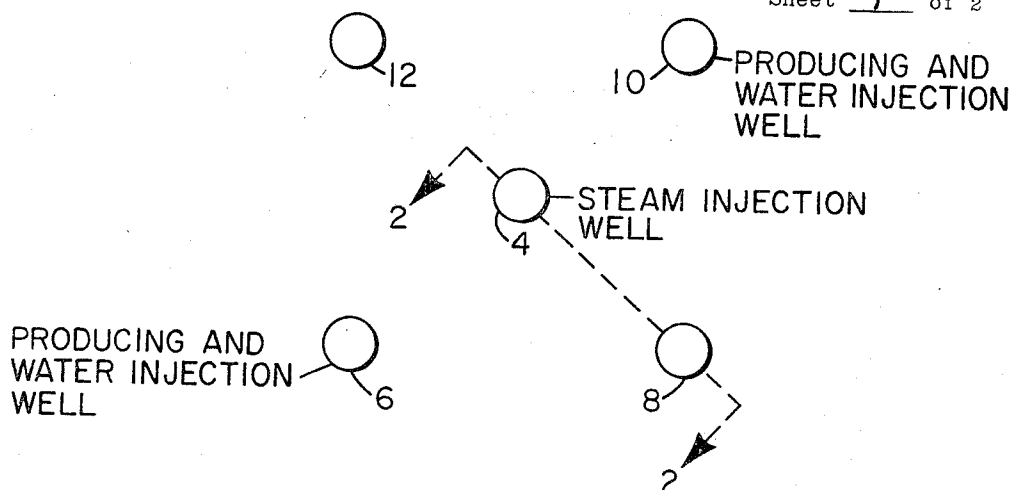


FIG. 1

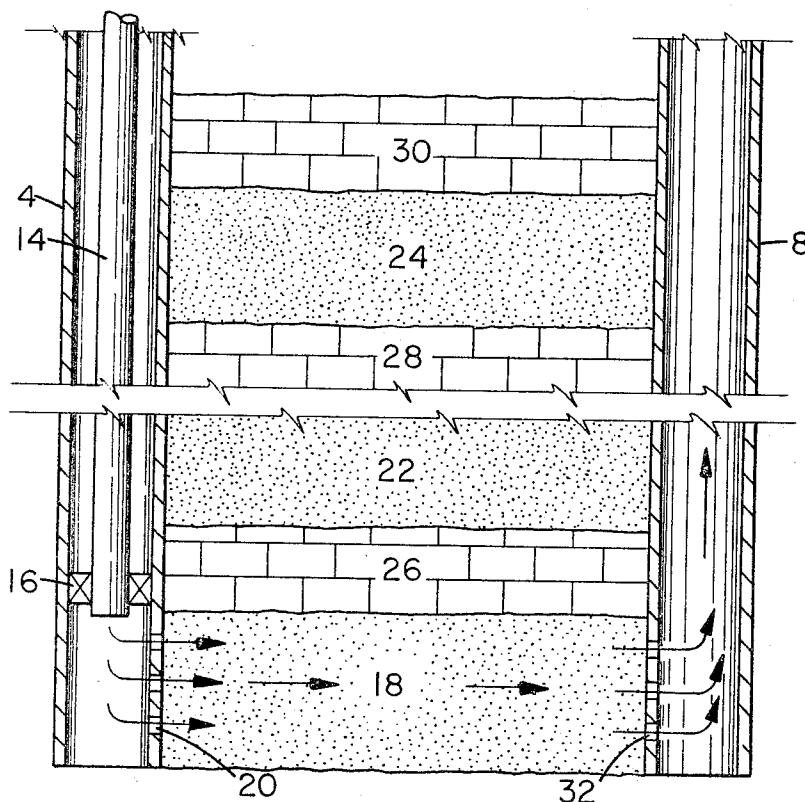


FIG. 2

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Filed Dec. 16, 1966

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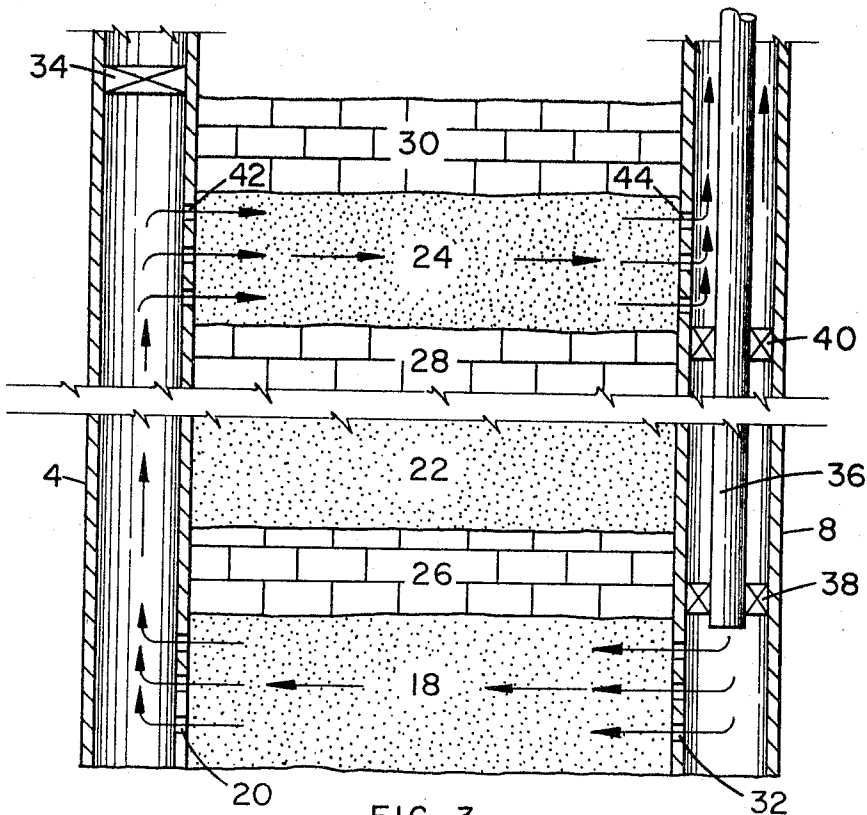


FIG. 3

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RECOVERY OF PETROLEUM BY THERMAL METHODS INVOLVING TRANSFER OF HEAT FROM ONE SECTION OF AN OIL-BEARING FORMATION TO ANOTHER

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Filed Dec. 16, 1966, Ser. No. 602,395

U.S. Cl. 166—256

Int. Cl. E21b 43/24, 43/20

8 Claims

ABSTRACT OF THE DISCLOSURE

After finishing one thermal recovery project, the heat from one stratum is extracted to be used in a superjacent or subjacent stratum. In the case of oil recovery by means of steam injection the heat is extracted not by flow from the producing wells, but by flow from the injection wells, such fluids having been originally injected into the producing wells. In effect the injected fluids are "backed up" to the hotter injection wells. With pay zones that have been subjected to forward or direct combustion the flow of cooler fluid is reversed, i.e., said fluids enter the burned out pay zone, via the injection wells backing the heat out of said zone into the producing wells. The resulting hot fluid may then be transferred to another oil bearing zone penetrated by said producing wells or removed therefrom and introduced into pay zones penetrated by still other wells.

The present invention relates to the production of petroleum from underground deposits thereof by means of thermal recovery techniques. More particularly it is concerned with, but not limited to, the recovery of petroleum of the kind which lends itself to production by combustion or steam injection methods, typically heavy oils having an API gravity of not more than about 25°. The invention is especially directed to a means for conservation of heat used in the aforesaid method for the recovery of heavy oils from thick reservoirs, e.g., at least 50 ft. of net pay in the case of multiple oil bearing zones separated by non-oil-bearing formations or at least 100 ft. in the case of a continuous pay zone. In this connection, the expression "thick reservoir" as used in the present description and claims is intended to include both the multi-zone hydrocarbon containing reservoirs separated by non-oil-bearing zones, as well as thick continuous petroleum deposits.

Background of the invention

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 dur-

ing which no production is obtained. Also, the relative permeability of the formation to oil decreases owing to the increase in water saturation. Moreover, in thermal recovery methods the cost of steam, or air in the case of combustion, is often a major factor in determining the success or failure of such a project. Typically, it costs about 1¢ to inject a barrel of cold water, and about 27.5¢ to inject a barrel of water as steam into a formation. In California alone about 65,000 barrels of oil per day are now being produced by steaming techniques. At the typical ratio of 2 barrels of steam per barrel of oil this means about \$40,000 worth of heat is being injected into the ground every day by means of steam alone. Most of this heat remains in the ground unused if only current techniques are employed.

By the process of our invention, however, we are able to conserve and reuse injected or generated heat in the thermal recovery of oil, thus not only substantially improving the efficiency of such procedures, but in many instances widening the field of economic use thereof.

Brief description of the drawings

In the accompanying drawings:

FIGURE 1 is a diagrammatic representation of one embodiment of our invention showing wells arranged in a five-spot pattern, the oil-bearing zones being separated by non-oil-bearing formations penetrated by a central injection well and surrounded by producing wells at least some of which are equipped to be used simultaneously as injection wells.

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

FIGURE 3 illustrates a later stage of our invention being applied to the system generally shown in FIGURE 2.

Description of the preferred embodiments

In carrying out an embodiment of our invention, and referring to FIGURES 1, 2 and 3, we have wells arranged in a five-spot pattern with the central well 4 serving as the steam injection well and perimeter wells 6, 8, 10 and 12 operating as producers. In initiating the process, steam at 400° to 670° F. at pressures of 250 to 2500 p.s.i. is injected down tubing 14, set on packer 16 into lowermost oil sand 18 via perforations 20 resulting in the flow of oil up the casing of well 8. Oil sands 18, 22 and 24 are separated from one another by shale stringers or non-oil-bearing zones 26, 28 and 30. Steam injection is continued at a rate of from about 6,000 to about 20,000 lbs. per hour until steam breakthrough into well 8 is observed or until it becomes uneconomical to produce oil from sand 18 through perforations 32. Such injection and production steps may vary from periods of from a number of months to several years, depending on the nature of the oil, the thickness of the formation being flooded with steam, well spacing, and steam injection rate.

After the initial steam injection step, tubing 14 and packer 16 may be removed from well 4 and a bridge plug 34 set at a location just above oil sand 24 as shown in FIGURE 3; or if more expedient to do so, tubing 14 may be raised to a point just above sand 24, shut in, and packer 16 reset opposite shale section 30. Next, relatively cool water, e.g., 50° to 80° F., is then introduced at a rate of from about 250 to about 3000 barrels per day into hot, depleted oil sand 18 via perforations 32 and tubing 36 set on packers 38 and 40. The water thus injected picks up heat from formation 18, flows into well 4 up the casing and to oil bearing sand 24 via perforations 42. The oil in sand 24 is reduced substantially in viscosity and is forced to flow into well 8 through perforations 44 and produced up the annulus as shown.

Water injection in the manner just described is continued until the fluids entering well 4 are not more than

about 50° to about 100° F. above formation temperature after which steam is injected into a packed off zone opposite perforations 42. By thus preheating said zone, steam injectivity is improved. Steam injection is carried out under conditions similar to those described above until breakthrough or until further introduction thereof is uneconomical.

Thereafter the above recited procedure can be repeated with respect to the remaining oil-bearing zones until they all have been effectively steam flooded, bearing in mind that when water is injected into a zone that has just been steam flooded, it is preferable to introduce the resulting hot water into the coldest of the untreated oil-bearing zones to realize the most efficient utilization of heat.

The process of our invention may be varied from the procedure described above without departing from the scope thereof by first effecting combustion in one of the oil-bearing zones, producing the oil therein and then flooding the resulting hot burned out zone with water to accumulate the heat therefrom and then injecting this hot water into another cooler oil-bearing zone prior to conducting combustion or steam flooding in said cooler zone. The manner in which the heat is initially supplied to the formation being treated is unimportant. It should be emphasized however that by our injection a substantial amount of heat which would otherwise be lost can be reused. The novel concept of our invention resides in the fact that maximum use of such heat can be obtained by introducing a cooler fluid such as water into the burned out or steamed out zone, picking up the heat in the latter and transferring the resulting hot fluid into another cooler oil-bearing zone. This technique need not necessarily be limited to a single group of wells but it is likewise applicable to more than one multiple well pattern where the hot water or similar fluid may, if desired, be pumped from the steamed or burned out zone into a cooler oil-bearing zone via another well which is not a part of the five-spot pattern mentioned above. Also, where more than one group of wells is available in a field for treatment in accordance with our invention, maximum use of equipment such as boilers in the case of steam injection, or compressors in the case of combustion, can be realized by carrying out the combustion or steam injection steps in one of such group of wells followed by injection of cold water as taught herein. While the water is being thus introduced, steam injection or combustion can be effected in the second of a multiple well pattern in accordance with the method set forth above.

While it is ordinarily not considered feasible to heat a thick, e.g., 200 ft., formation with a practical size (20,000 lbs./hr.) boiler to recover heavy oil, the process of our invention renders it possible to treat such formations, taking a relatively thin (e.g., 25 ft.) section thereof at a time and otherwise producing in the same fashion as described above. Also, it may be desirable to conduct combustion in an oil-bearing zone after the latter has been flooded with hot water. In such instances, the subsequent combustion process is most efficient owing to more efficient utilization of oxygen. Additional water injection can be carried out in this same zone after combustion and the heat transferred to another sand, in accordance with our invention.

Although others have proposed the use of water to flood a heated reservoir for the purpose of recovering heat therefrom, such operations contemplate continuing flooding from the same injection well or wells. By the process of our invention, however, we inject water into the hot formation via the original producing well or wells and in this way we "back" the heat out of the reservoir, producing hot fluids from the original injection well. In the case of steam injection or reverse combustion, for example, the original injection well is hotter than the producing well. Having been heated longer, the reservoir in the vicinity of said injection well is less susceptible to

heat losses. Thus our invention makes possible the recovery of a larger portion of the heat at higher and more useful temperatures.

The term "thin" as used herein is intended to refer to the vertical dimension (not more than about 25 ft.) of one of a plurality of oil-bearing zones separated by non-oil-bearing zones, or the vertical distance heat penetrates a section of a thick oil-bearing zone when steam injection or combustion is carried out in such section.

We claim:

1. In a method for the recovery of petroleum from an underground deposit thereof by thermal means, said deposit being penetrated by an injection well and a producing well, the improvement which comprises:

heating a first thin section of said deposit substantially throughout the distance between said wells by a process wherein a fluid is injected into said first thin section through said injection well and oil is recovered through said producing well, and at the termination of said process the temperature at said injection well is higher than that at the producing well, thereafter introducing a fluid via the lower temperature well into the resulting heated section and flowing said fluid into the higher temperature well, the injection temperature of said fluid being substantially lower than that of said heated section,

continuing the introduction of said fluid until the temperature thereof as it enters said higher temperature well is not more than about 50° to 100° F. higher than the normal temperature of said deposit,

next utilizing the heat in the resulting hot fluid by injecting the latter into a second section of said deposit penetrated by said injection well to force the oil therefrom into said producing well, and

thereafter subjecting said second section to a thermal recovery method by introducing into said second section via one of said wells a fluid selected from the group consisting of steam and air to force oil from said second section into the other of said wells.

2. The method of claim 1 wherein the fluid injected in the heating of said first thin section is steam.

3. The method of claim 1 wherein the heating of said first thin section is accomplished by reverse combustion and the fluid introduced into said first section to effect the heating step is air.

4. The method of claim 1 wherein the fluid used to extract heat from said heated section is water.

5. The method of claim 1 in which said second section is remote from said first section.

6. In a method for the recovery of petroleum from an underground deposit thereof by thermal means, said deposit being penetrated by an injection well and a plurality of producing wells surrounding said injection well, the improvement which comprises:

heating a first thin section of said deposit substantially throughout the distance between said injection well and said producing wells by a process wherein a fluid is injected into said first thin section through said injection well and oil is recovered through said producing wells and at the termination of said process the temperature of said first thin section adjacent said injection well is higher than at said producing wells,

thereafter introducing water into the resulting heated thin section via at least one of said producing wells, the injection temperature of said water being substantially lower than that of said heated section, continuing the introduction of water until the temperature thereof as it enters said injection well is not more than about 50° to about 100° F. higher than the normal temperature of said deposit,

next utilizing the heat in the resulting hot water by introducing the latter via said injection well into a second section of said deposit penetrated by said in-

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jection and producing wells, said second section being remote from said first section to force oil therefrom into at least one of said producing wells, and thereafter subjecting said second section to a thermal recovery method by introducing into said section via said injection well a fluid selected from the group consisting of steam and air to force oil from said second section into said producing wells.

7. The method of claim 6 in which the fluid injected in the heating of said first thin section is steam.

8. The method of claim 6 in which the heating of said first thin section is accomplished by reverse combustion and the fluid introduced into said first section is air.

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U.S. Cl. X.R.

166—263

**UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION**

Patent No. 3,430,700

March 4, 1969

Abdus Satter et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 14, "unusued" should read -- unused --. Column 5, line after "said" insert -- second --.

Signed and sealed this 24th day of March 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, Jr

Commissioner of Patents