

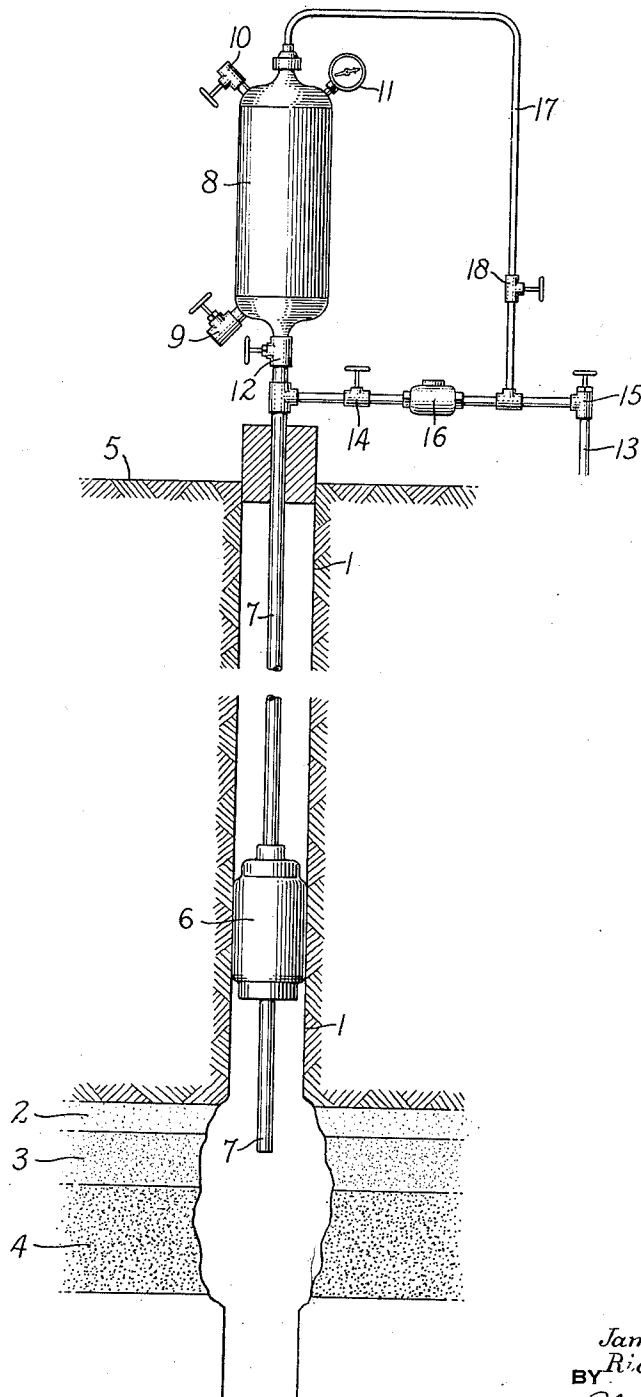
Nov. 25, 1941.

R. M. HASKELL

2,264,037

METHOD OF RECOVERING OIL

Filed Feb. 3, 1937



INVENTORS
James A. Lewis
Richard M. Haskell
 BY *Blair, Curtis + Dunne*
 ATTORNEYS

1023
 X1041
 X104

Patented Nov. 25, 1941

2,264,037

UNITED STATES PATENT OFFICE

2,264,037

METHOD OF RECOVERING OIL

Richard M. Haskell, Bradford, Pa., assignor to
Case, Pomeroy & Company, Inc., New York,
N. Y., a corporation of Delaware

Application February 3, 1937, Serial No. 123,812

10 Claims. (Cl. 166—21)

This invention relates to a method of recovering oil from subterranean oil-bearing formations.

It has been the practice, in recovering oil from producing wells that are approaching depletion, to force water through the oil-bearing formation from points distant from the producing wells for the purpose of driving the oil into the latter. This formation usually consists of several strata of sandstone or the like, having widely different textures and pore sizes that determine their permeabilities.

This method has been accomplished by drilling inlet wells substantially equi-distant from a producing well to the lower level of the oil-bearing formation, plugging the inlet wells above the oil-bearing formation and forcing water into the oil-bearing formation below the plug under sufficient pressure to drive the oil through the interstices of the strata into the producing well.

This method has proven unsatisfactory because of the fact that the water, after driving the oil from the stratum having the greatest permeability to the producing well, continues to flow through the then oil-freed pores of the exhausted stratum and enters the producing well in such quantities that it sometimes necessitates the abandonment of the producing well before all of the available oil has been recovered from the formation.

This abandonment has been found necessary because, in order to drive the oil from the strata of lesser pore sizes or permeability, large quantities of water must be forced into the formation to compensate for the free flow of the water through the oil-freed stratum, with the result that an unjustifiable amount of water reaches the producing well. The cost of lifting the large quantities of water with relatively small amounts of oil from the producing well and of pumping the water into the inlet wells makes the continuation of the process uneconomical.

The relative sizes of the pores in the various strata are readily determinable. For example, in some instances, where there are three strata, it has been found that the sizes of the pores bear a relationship of three hundred to fifteen to five. Thus, when water or other fluid is forced through a formation of this character, where the strata are of substantially equal thicknesses, the water will move toward the producing well twenty times as fast in the first stratum as it does in the second, and sixty times as fast in the first stratum as it does in the third. The result of this will be that, when the stratum of the greatest permeability has been freed of oil and water is flow-

ing through this stratum, all of the oil will not have been driven from the remaining strata but the quantitative relationship of the water and oil entering the producing well will be such that it will be uneconomical to continue the operation.

The method that constitutes the subject matter of this invention consists, broadly, in driving the oil through the strata by means of fluid under pressure and selectively and progressively sealing the strata after they have delivered all of their oil to the producing well, and thereafter continuing the driving of the oil from the remaining strata to the producing well.

This method is accomplished by driving the oil from the successive strata in the order of their reduced permeabilities, and successively sealing off the strata after the oil has been exhausted therefrom by means of a slurry which includes solid particles of such sizes that they will enter and seal off the pores in only the stratum that has been freed of its oil.

The drawing illustrates, conventionally, an apparatus for carrying out the method above outlined.

In this drawing an inlet well 1, that extends into the oil-bearing strata 2, 3 and 4 from the surface 5 of the ground, is illustrated. A number of these inlet wells are driven substantially equi-distant from the producing well in any desired geometrical arrangement such as now employed.

Each inlet well is equipped with a packer or plug 6, which may be of any of the forms now commercially in use or of any other desirable form, to plug the well above the oil-bearing strata so that when water is forced into the well below the plug it may not escape upwardly through the inlet well.

In order that the inlet well may alternately be supplied with water under pressure and with a slurry, also under pressure, below the plug 6, a tube 7 is provided which extends through the plug 6 to a point below the same and adjacent the oil-bearing strata. This tube is connected with a slurry reservoir 8 which is provided with a drain valve 9, a vent valve 10, and a pressure gauge 11. The connection between the tube 7 and the slurry reservoir 8 is through a valve 12. A water supply conduit 13 which has valves 14 and 15 and a water meter 16 interpolated therein is connected to the tube 7 below the valve 12.

A water bypass 17, having a control valve 18 interpolated therein, is connected to the slurry reservoir 8 and to the water supply conduit 13

on the side of the valve 15 remote from the water source.

It is, of course, to be understood that the water supply conduit 13 may be connected to a water supply where the pressure may be varied at the will of the operator.

In carrying out the method with the apparatus above described, after the oil has been driven from the stratum having the greatest permeability the reservoir 8 is filled with a slurry, preferably of water and a quick-setting cement, and this slurry is forced into the inlet well in the location of the oil formation by means of water under pressure from the supply conduit 13 and the bypass 17. During this operation, the valve 14 is closed and the valves 12, 15 and 18 open. After the slurry has been completely forced from the reservoir 8 into the well, the flow of the water is continued through the bypass 17 to clear the reservoir and the tube 7 of the slurry.

The reservoir may then be removed, the valves 12 and 18 closed, the valve 14 opened and the water, under pressure, caused to flow from the source through the conduit 13 and the tube 7 to the well, or the water may be caused to thus flow without the removal of the reservoir 8.

In creating the slurry, a solid material, having grain sizes sufficiently small to permit the material to enter the pores of the stratum of the greatest permeability but too large to permit it to enter the pores of the strata of the lesser permeability, is selected. As the solid particles of the slurry are sufficiently small to remain in suspension in the water, as the velocity of the water entering the stratum of the greatest permeability is relatively high, and as the solid particles are too large to enter the pores of the remaining strata, these solid particles enter the pores of the stratum having the greatest permeability and the water pressure forces them into the tortuous passages of this stratum. The continued flow of the water into the inlet well after the slurry has been exhausted from the reservoir will drive the solid particles of the slurry farther back into the stratum that is being sealed off, with the result that the pores therein will be blocked, eventually, to form a dam.

It is, of course, possible that one or more charges of slurry from the reservoir may be necessary to effectively seal any given stratum or, otherwise stated, the amount of slurry used may vary with the different strata.

As has been explained, the solid particles of the slurry are sufficiently larger than the pores of the unexhausted strata that they will not enter these pores, and thus only the exhausted stratum will be sealed off, leaving the unexhausted strata in condition for subsequent treatment by water under pressure.

After the exhausted stratum has been sealed off the supply of water under pressure to the inlet well is continued so as to drive the oil through the unexhausted strata. The progress of the oil through the stratum with the next greatest permeability will be greater than that in the strata of lesser permeability. Because of this, the successive stratum may be exhausted of oil and sealed, and if the process is carried to its ultimate end, all of the recoverable oil will be driven from the various strata to the producing well without forcing an unjustifiable amount of water into the producing well.

It is to be realized that, with the stratum or strata of the greater permeabilities being sealed off, the water pressure may be increased to more

rapidly drive the oil through the remaining oil-bearing strata, with the result that the time consumed may be greatly reduced.

The results of this process are the greater production of oil from wells that are nearing depletion and the more economical and more rapid recovery of the oil, the economy being effected, not only in the raising of lesser quantities of water from the producing well, but also in the use of lesser quantities in the inlet well for a shorter period of time.

I have given as an illustrative example of slurry one that is made up of water and cement; but it is, of course, to be understood that other fluids and other solid particles that have the ability to remain in suspension and have controllable grain sizes may be used, and the nature of the fluid and the particles may be determined after the permeabilities of the various strata have been examined and determined.

While I have illustrated the use of a slurry reservoir in connection with this method, it is to be understood that the method may be otherwise carried out as, for instance, with a pump, a proportional pump, an injector or by hand.

I claim:

1. The method of recovering oil from subterranean strata having different permeabilities and located between a producing well and an inlet well that includes forcing a fluid into the inlet well to drive the oil through the strata until the stratum of the greatest permeability is freed of oil, thereafter forcing a slurry, having grain sizes sufficiently small to permit the solid material of the slurry to enter the pores of the stratum of greatest permeability and sufficiently large to prevent the solid material from entering the pores of the strata of lesser permeability, into the inlet well and forcing a fluid into said inlet well to free the succeeding strata of oil.

2. The method of recovering oil from subterranean strata having different permeabilities and located between a producing well and an inlet well that includes forcing a fluid into the inlet well to drive the oil from the stratum having the greatest permeability, forcing a slurry, having grain sizes sufficiently small to permit the solid material of the slurry to enter the pores of the stratum having the greatest permeability and sufficiently large to be excluded from the pores of the strata of lesser permeability, into the inlet well, forcing fluid under pressure into the inlet well to drive the solid material farther into the pores of the stratum having the greatest permeability and thereafter continuing the flow of fluid to drive the oil through the strata having the lesser permeabilities.

3. The method of recovering oil from subterranean strata having different permeabilities and located between a producing well and an inlet well that includes forcing a fluid into the inlet well to drive the oil from the stratum having the greatest permeability, forcing a slurry, having grain sizes sufficiently small to permit the solid material of the slurry to enter the pores of the stratum having the greatest permeability and sufficiently large to be excluded from the pores of the strata of lesser permeability, into the inlet well, forcing fluid under pressure into the inlet well to drive the solid material farther into the pores of the stratum having the greatest permeability and then subsequently increasing the pressure of the fluid entering the inlet well.

4. A process for recovering oil from subterranean oil bearing strata having different per-

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meabilities, which comprises the steps of establishing and maintaining an output well spaced from an input well, forcing fluid down said input well to drive the oil from the strata into said output well, and injecting into the input well a substance itself adapted to obstruct the flow of fluid through a more permeable oil depleted strata without obstructing the flow of fluid through less permeable oil-bearing strata, and thereafter resuming the injection of fluid into non-sealed oil-bearing strata to drive oil therefrom into said output well.

5. In the production of oil by water-flooding from an intake well, the method of selective sealing off of oil-depleted strata having larger pores and greater permeability in preference to oil-producing strata having smaller pores and lesser permeability, comprising introducing into an intake well a slurry particles of which have a grain size sufficiently small to enter the pores of the stratum to be sealed off but too large to enter the smaller pores of the oil-producing strata, forcing said slurry under pressure into said well whereby it enters and plugs the said stratum having the larger pores and greater permeability in preference to the strata having the smaller pores and lesser permeability.

6. In the production of oil by water-flooding from an intake well, the method of the selective sealing-off of oil-depleted strata having greater permeability in preference to oil-producing strata having lesser permeability, comprising introducing into the intake well a slurry the particles of which have a grain size sufficiently small to enter the pores of the stratum to be sealed off, forcing said slurry under such reduced pressure that it enters the depleted stratum having the greater permeability in preference to the strata having the lesser permeability whereby the stratum having the greater permeability is eventually plugged by the entering material.

7. A process for recovering oil from porous strata which comprises establishing and maintaining a water input well down which water is forced into surrounding strata, of various permeabilities, establishing and maintaining an oil output well spaced from the input well and from which oil and water are withdrawn, and when the ratio of water to oil produced at the output well becomes unduly high, injecting into the input well a material of such character and in such amount as to partially obstruct the several porous strata adjacent the input well, and then resuming injection of water.

8. A process for recovering oil from subterranean oil-bearing strata having different permeabilities, which comprises the steps of establishing and maintaining an output and input well, forcing fluid down said input well to drive

oil from the strata into said output well spaced from the input well, and injecting into the input well an aqueous suspension of finely divided particles adapted to obstruct the flow of fluid through a more permeable non-oil-bearing stratum without obstructing the flow of fluid through less permeable oil-bearing strata and thereafter resuming the injection of fluid into non-sealed oil-bearing strata to drive oil therefrom into said output well.

9. A process for recovering oil from subterranean oil-bearing strata having different permeabilities which comprises the steps of establishing and maintaining an output well spaced from an input well, forcing fluid down said input well to drive the oil from the strata into said output well and, after the injected fluid has forced the oil from the more permeable strata, injecting a fluid vehicle carrying a substance into the input well under such reduced pressure that the fluid vehicle and substance enter the oil-depleted strata having the greater permeability in preference to the strata having the lesser permeability, said substance being adapted to obstruct the flow of fluid through the permeable strata entered by said fluid vehicle and substance without obstructing the flow of fluid through less permeable strata not entered by said fluid vehicle and substance and thereafter resuming the injection of fluid into the well and strata to drive oil from the remaining unobstructed strata into said output well, whereby the ratio of oil to fluid produced at the output well is increased.

10. A process for recovering oil from subterranean oil-bearing strata having different permeabilities which comprises the steps of establishing and maintaining an output well spaced from an input well, forcing water down said input well to drive the oil from the strata into said output well and, after the injected water has forced the oil from the more permeable strata, injecting a liquid vehicle carrying a substance into the input well under such reduced pressure that the liquid vehicle and substance enter the oil-depleted strata having the greater permeability in preference to the strata having the lesser permeability, said substance being adapted to obstruct the flow of water through the permeable strata entered by said liquid vehicle and substance without obstructing the flow of water through less permeable strata not entered by said liquid vehicle and substance and thereafter resuming the injection of water into the well and strata to drive oil from the remaining unobstructed strata into said output well, whereby the ratio of oil to water produced at the output well is increased.

RICHARD M. HASKELL.