Jan. 12, 1965 M. SANTOURIAN 3,165,154

OIL RECOVERY BY IN SITU COMBUSTION

Filed March 23, 1962

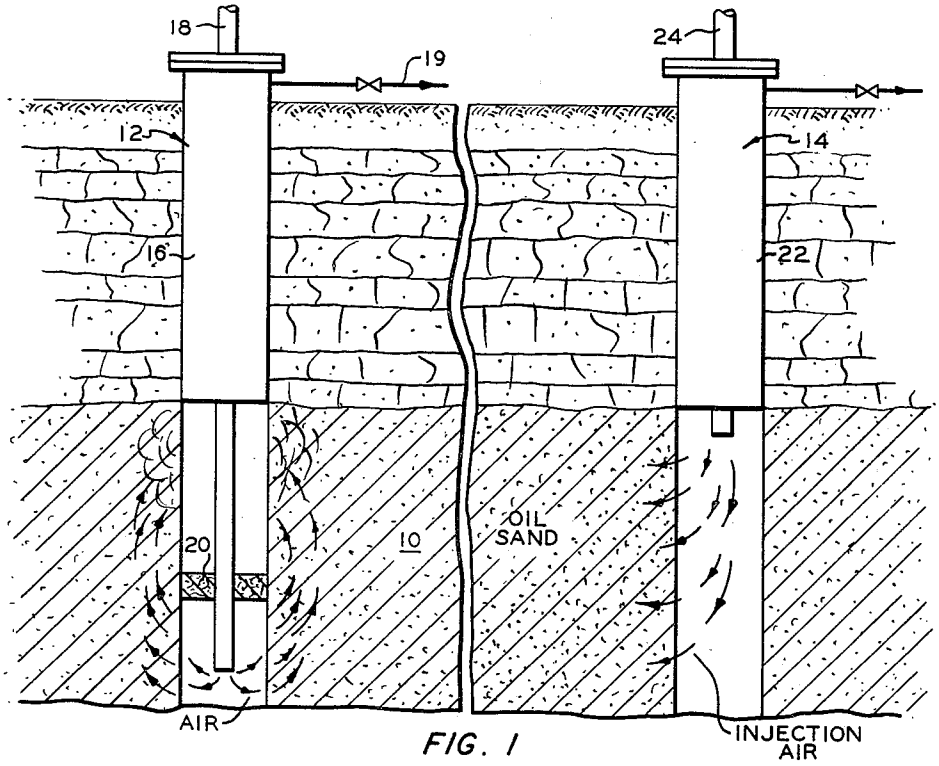

FIG. 1

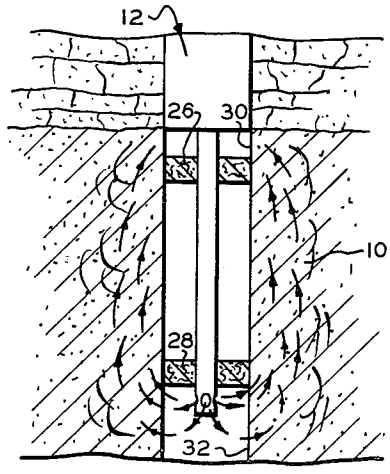

FIG. 2

INVENTOR.
MELCON SANTOURIAN

BY Young & Quigg

ATTORNEYS

United States Patent Office 3,165,154 Patented Jan. 12, 1965

3,165,154

OIL RECOVERY BY IN SITU COMBUSTION

Melcon Santourian, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

Filed Mar. 23, 1962, Ser. No. 182,013
10 Claims. (Cl. 166—11)

This invention relates to a process for recovering oil by in situ combustion from a permeable stratum containing hydrocarbons.

The recovery of oil by in situ combustion involves establishing a combustion zone within a carbonaceous stratum around an ignition well and moving the combustion zone thru the stratum to one or more offset wells either by direct injection of combustion-supporting gas, such as air, thru the ingnition well or thru the offset well (or wells) so as to move the combustion zone inversely to the flow of said gas. The former technique is considered a direct drive process while the latter is usually designated an inverse drive process. It is, of course, desirable to ignite the stratum throughout its entire thickness around the ignition well in order to produce as much stratum as possible on a given burnthru. However, it is difficult to ignite an oil-bearing stratum over the entire cross section thereof by conventional practices.

This invention is concerned with a method or technique for igniting a thick stratum over its entire thickness around an ignition well and moving the resulting combustion zone thru the stratum toward one or more offset wells.

Accordingly, the principal object of the invention is to provide an improved process or technique for producing thick oil-bearing strata. Another object is to combine a vertical drive in situ combustion process with a horizontal drive process so as to produce the entire thickness of the stratum being produced. A further object is to provide an improved technique for igniting a permeable carbonaceous stratum around an ignition well thruout the thickness of the stratum. 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 comprises establishing an annular combustion zone around an ignition well within an oil-bearing stratum which extends from the top to the bottom of the stratum, by igniting the stratum adjacent one end section of the annular zone and passing combustion-supporting gas vertically therethru so as to expand the combustion zone to the opposite end section of the anulus and, thereafter, passing combustion-supporting gas radially into the annular combution zone so as to advance the same radially outwardly toward one or more offset wells in the stratum. The anular combustion zone around the ignition well may be established by either direct or inverse drive by inserting tubing in the well, positioning one or more packers on the tubing within the stratum, and feeding air or other combustion-supporting gas either thru the annulus and producing thru the tubing, or vice versa. The ignition may be effected either in an upper section of the stratum above the packer or packers or in a section of the stratum below the packer or packers. By igniting an upper section of the stratum and feeding air thru the well anulus, the combustion zone is expanded by direct drive to the lower section of the stratum. By igniting the upper section of the stratum and injecting thru the tubing, the combustion zone is expanded by inverse drive with production thru the annulus of the well.

After combustion has been established in an annulus around the ignition well in the aforesaid manner, air is injected into the combustion zone or thru the ignition well so as to advance the combustion zone toward the offset well or wells by direct drive, or air is injected thru the offset well or wells so as to advance the annular combustion zone toward the injection well or wells by inverse drive.

A more complete understanding of the invention may be had by reference to the accompanying drawing in which FIGURE 1 is an elevation in partial section thru an ignition well and an offset well in a carbonaceous stratum illustrating one embodiment of the invention and FIGURE 2 is a fragmentary elevation in partial section of another arrangement of apparatus in an ignition well for effecting the invention.

Referring to FIGURE 1, a carbonaceous stratum or oil sand 10 is penetrated by an ignition well 12 and an offset well 14. Well 12 is provided with casing 16 and tubing 18 extending from a lower level of the stratum thru the well head. A packer 20 is set on tubing 18 at an intermediate level in stratum 10.

Well 14 is provided with a casing 22 and a tubing string 24. Well 14 may represent one of a ring of wells surrounding well 12 or it may represent one of a line of wells parallel with a line of ignition wells 12, there being another line of these wells 14 on the opposite side of a line of the ignition wells 12.

FIGURE 2 illustrates an alternative arrangement of packers in well 12 wherein a packer 26 is positioned at an upper level in stratum 10 and packer 28 is positioned at a lower level therein. In this arrangement there is an upper section 30 of stratum above packer 26 exposed to the well and a lower section 32 below packer 28 exposed to the well.

It is also feasible to extend casings 16 and 22 thru stratum 10, providing perforations are made in the casing at higher and lower levels therein. However, due to the probability of overheating and fusing of the casing, it is preferred to terminate the casing adjacent the top of the formation.

In operating with the arrangement illustrated in FIGURE 1, the section of stratum 10 above packer 20 is ignited by means of a charcoal pack which is ignited by dropping a railroad fusee or other ignition device on the charcoal and either passing air or other combustion-supporting gas thru tubing 18 to establish an inverse vertical drive of the combustion zone along the well wall or thru line 19 and the well annulus so as to drive the combustion zone by direct drive to the lower section of the stratum below packer 20. When air is injected thru the annulus, produced gases are vented thru tubing 18 and passed to separation and recovery apparatus (not shown). When air is injected thru the tubing 18, produced gases are passed thru line 19 to recovery means.

It is also feasible to place a charcoal or other solid fuel pack in the bottom of well 12 before packer 20 is positioned and then igniting the bottom of the fuel pack by dropping a fusee or other ignitor down the tubing string 18 and either injecting air thru the tubing string or thru line 19 so as to burn the fuel pack, ignite the adjacent stratum below packer 20, and drive the resulting combustion zone around packer 20 into the upper section of the stratum.

A preferred arrangement of packers is illustrated in FIGURE 2. By igniting the stratum either above packer 26 or below packer 28 in the manner described above, and passing air either thru the annulus or thru the tubing, the ignited area is expanded from section 30 to section 32 or vice versa, depending upon where the ignition is initiated. This arrangement is more effective in extending the combustion zone in the stratum from the uppermost to the lowermost area thereof around well 12. The arrangement of FIGURE 2 is preferred when producing thick strata.

After establishing an annular combustion zone around well 12 extending substantially the thickness of the stratum, it is desirable to remove packer 20 or packers 26 and 28, in case the arrangement of FIGURE 2 is utilized. Thereafter, in the event inverse drive of the combustion zone is to be practiced, air is injected thru well 14 so that it passes thru stratum 10 into the combustion zone around well 12, thereby causing the combustion zone to advance toward well 14. Of course, the annular combustion zone around well 12 is preferably advanced radially outwardly into the stratum in all directions by injecting air thru a ring of surrounding wells. In the event direct drive of the annular combustion zone is to be utilized, air is injected thru well 12 and the combustion front is driven toward the surrounding wells 14 with production being recovered thru tubing 24 or the annulus and line 25.

In thick strata containing highly viscous oil, it is impossible to utilize direct drive either vertically along the ignition well or horizontally toward the offset wells. With such strata, direct drive of the combustion zone causes plugging of the stratum due to the driving of hot liquid oil into the cool stratum outside the combustion zone where the oil congeals and prevents flow of gases thru the stratum, thereby preventing arrival of air in the combustion zone and causing the fire to die out. Hence, in most strata it is preferred and necessary to utilize inverse drive of the combustion fronts or zones.

It is impossible to advance a combustion front by inverse drive using inverse air injection thru the offset wells in strata containing substantially no gaseous hydrocarbon. In operating in such strata it is necessary to incorporate in the injected air or other combustion-supporting gas from 1 to 3 or 4 volume percent of fuel gas, such as the light normally gaseous hydrocarbons or L.P.G. The arrival of the fuel in the combustion front in admixture with excess oxygen causes the combustion of the fuel gas which maintains a sufficiently high temperature in the combustion front to burn some of the inplace hydrocarbons and produce oil from the stratum.

It is within the scope of the invention to ignite the stratum by any suitable means, although ignition with a charcoal pack burned in contact with the stratum by passing air thereto (which may contain a small concentration of fuel gas) is preferred. The essence of the invention is the establishment of an annular combustion zone around the ignition well by vertical drive and extending the combustion zone outwardly from the ignition well by either direct or inverse horizontal drive.

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.

I claim:

1. A process for producing hydrocarbons from a permeable carbonaceous stratum penetrated by an ignition well and at least one offset well which comprises providing said ignition well with a tubing string extending to a lower level of said stratum; positioning a packer around said tubing at an intermediate level of said stratum dividing same into an upper level and a lower level; while maintaining said at least one offset well closed in, conducting a first combustion phase by igniting said stratum at a selected one of said upper and said lower level; passing

combustion-supporting gas directly into the resulting combustion zone at the selected level from one of the tubing and the annulus of said ignition well so as to expand said zone thru an annular section of stratum to the other of said levels by direct drive; thereafter conducting a second combustion phase by passing said gas to the resulting annular combustion zone from one of said ignition well and said offset well so as to move said combustion zone toward said offset well; and recovering hydrocarbons produced by the second phase combustion from one of said wells.

2. The process of claim 1 wherein said stratum is ignited at said upper level; said combustion-supporting gas is injected thru the ignition well annulus so as to move said combustion zone by direct drive to said lower level; and gases produced by said first combustion phase are produced thru said tubing string.

3. The process of claim 1 wherein said combustion-supporting gas for said second combustion phase is injected thru said at least one offset well so as to move said zone by inverse drive toward said offset well; and gases produced by said second combustion phase are recovered from said ignition well.

4. The process of claim 1 wherein said combustion-supporting gas for said second combustion phase is injected thru said ignition well so as to move said combustion zone by direct drive toward said at least one offset well; and gases produced during said second combustion phase are recovered from said at least one offset well.

5. A process for producing hydrocarbons from a permeable carbonaceous stratum penetrated by an ignition well and at least one offset well which comprises providing said ignition well with a tubing string extending to a lower level of said stratum; positioning upper and lower packers on said tubing string at upper and lower levels of said stratum so as to leave an upper section of said stratum above said upper packer directly accessible thru the well annulus and a lower section of said stratum below said lower packer directly accessible thru said tubing; conducting a first combustion phase around said ignition well, while maintaining said at least one offset well closed in, by igniting one of said upper and lower sections; passing combustion-supporting gas directly into the resulting combustion zone from one of the tubing and annulus of said ignition well so as to expand said zone by direct drive thru an annular section of said stratum surrounding said ignition well and including said upper and lower sections; thereafter removing said packers and conducting a second combustion phase by passing combustion-supporting gas thru one of said ignition well and said offset well to the annular combustion zone so as to advance said zone thru said stratum toward said offset well; and recovering produced gases from said second combustion phase from one of said ignition well and said offset well.

6. The process of claim 5 wherein said upper section is ignited, said combustion-supporting gas is passed to the combustion zone thru said annulus, and gases produced by said first combustion phase are recovered thru the tubing.

7. The process of claim 5 wherein said lower section is ignited, said combustion supporting gas is passed to the combustion zone thru the tubing, and gases produced during said first combustion phase are recovered thru said annulus.

8. The process of claim 5 wherein said combustion-supporting gas for said second combustion phase is injected thru said at least one offset well so as to advance said combustion zone inversely to the flow of said gas, and produced gases from said second combustion phase are recovered thru said ignition well.

9. The process of claim 5 wherein said combustion-supporting gas for said second combustion phase is injected thru said ignition well so as to advance said combustion zone by direct drive, and produced gases from said second

combustion phase are recovered from said at least one offset well.

10. A process for producing hydrocarbons from a permeable carbonaceous stratum penetrated by an ignition well and at least one offset well which comprises establishing an annular combustion zone around said ignition well extending substantially from the top to the bottom of said stratum by igniting said stratum adjacent one end section of said annulus and passing combustion-supporting gas directly into the ignited section of said annulus so as to expand the resulting combustion zone to the opposite end

section of said annulus; thereafter passing combustion-supporting gas thru said at least one offset well and thru said stratum to said annular combustion zone so as to advance said zone toward said offset well; and recovering produced gases from said ignition well.

References Cited in the file of this patent

UNITED STATES PATENTS

3,026,937	Simm	Mar. 27, 1962
3,044,546	Dixon	July 17, 1962