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PETROLEUM PRODUCTION BY SECONDARY RECOVERY

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Fig. 1.

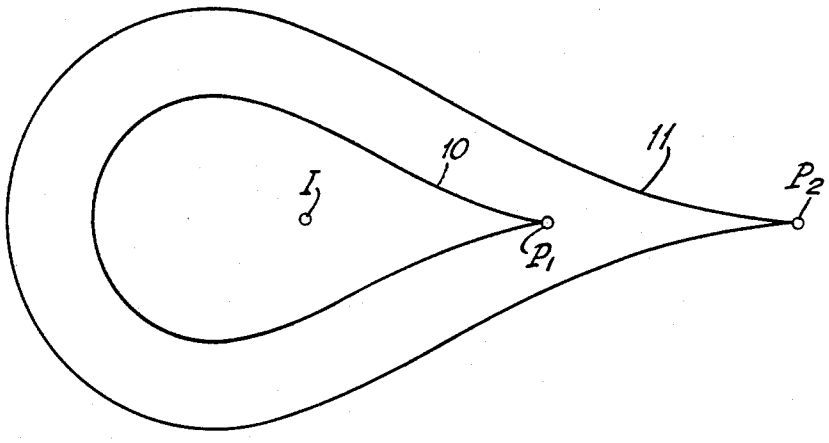
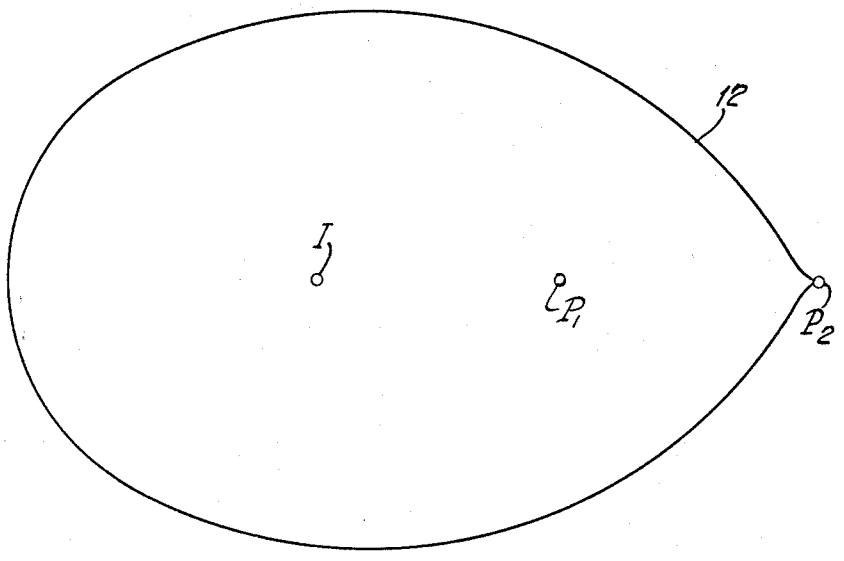


Fig. 2.



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PETROLEUM PRODUCTION BY SECONDARY RECOVERY

Donald L. Hoyt, Houston, Tex., assignor to Texaco Inc., New York, N.Y., a corporation of Delaware

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This invention relates to the production of petroleum from underground petroleum-producing formations. More particularly, this invention relates to a method for the production of petroleum from underground petroleum-producing formations so as to increase the overall production and recovery of petroleum therefrom.

In accordance with one embodiment this invention is directed to an improved secondary recovery operation wherein an extraneous fluid such as water or gas is introduced into an underground petroleum-producing formation to increase the recovery of petroleum therefrom.

In a petroleum producing operation wherein a plurality of wells are employed in the production of petroleum from underground petroleum-producing formations it has been the general practice in such operations when a production well produces an excessive amount of an extraneous fluid, such as water or gas, other than liquid petroleum, to shut-in that production well and to commence or carry out the production of petroleum via other production wells. It is known that in such instances a substantial amount of petroleum is usually left behind in the petroleum-producing formation but that this petroleum is not considered economically recoverable.

Accordingly it is an object of this invention to provide an improved method for the production and recovery of petroleum, particularly liquid petroleum, from underground petroleum-producing formations.

Another object of this invention is to provide a method whereby the amount of petroleum recovered from an underground petroleum-producing formation is increased.

Still another object of this invention is to provide an improved secondary recovery operation for the production and recovery of petroleum from underground petroleum-producing formations.

How these and other objects of this invention are achieved will become apparent in the light of the accompanying disclosure made with reference to the accompanying drawing which schematically illustrates an embodiment of the practice of this invention and wherein FIG. 1 is illustrative of a sweep pattern obtained in a conventional secondary recovery operation and FIG. 2 of a sweep pattern obtained in a secondary recovery operation in accordance with this invention.

In accordance with this invention an increased amount of petroleum is produced and recovered from an underground petroleum-producing formation by employing a plurality of wells penetrating said formation, more specifically, by employing at least three wells all of which are n-line and penetrating the petroleum-producing formation and by producing petroleum from the formation via the middle well of these three wells. The petroleum produced and recovered from said formation via the middle well is recovered for further treatment and handling and extraneous fluid, such as water or gas, produced along with the petroleum via the middle well is recovered and returned to the petroleum-producing formation via another one of the aforementioned three wells. Production of petroleum from the middle well is continued until an excessive amount of extraneous fluid is

produced and recovered along with the petroleum. In the meantime this extraneous fluid is recovered and returned to the formation via the aforesaid other well. When the amount of extraneous fluid produced from the petroleum-producing formation via said middle well along with the petroleum becomes excessive, production of petroleum from the petroleum-producing formation is then commenced via the third, remaining well, while at the same time maintaining production of the extraneous fluid and petroleum, if still produced, from the petroleum-producing formation via said middle well and returning the thus-produced extraneous fluid to the petroleum-producing formation via the aforesaid other well. In accordance with an embodiment of this invention production of petroleum from the petroleum-producing formation is commenced from the third well at about the same time as production is commenced from the middle well.

As indicated hereinabove the practice of this invention is also applicable to the recovery of petroleum from underground formations in a secondary recovery operation involving an injection well and at least two production wells, desirably there being one injection well per two production wells. In accordance with this embodiment of the invention injection fluid, such as water or gas, e.g. natural gas, is introduced into the petroleum-producing formation via the injection well. The production wells, at least two in number, are located in-line with respect to the injection well and on the same side thereof. In the initial stages of the secondary recovery operation the driving or injection fluid is injected into the petroleum-producing fomration via the injection well and the production of petroleum from said formation is carried out via the production well closer to the injection well. If desired, production is also carried out via the other production well. These operations are carried out substantially continuously or intermittently, as may be required or desired, with the return to the formation via the injection well of the injection fluid produced via the aforesaid closer production well along with the produced petroleum.

When an excessive amount of injection fluid is produced from the formation via the aforesaid closer production well along with the petroleum produced therefrom, while at the same time returning to the formation via the injection well added fresh injection fluid as required together with the injection fluid produced via the aforesaid closer well, production of petroleum from the formation is commenced via the production well farther removed from the injection well than the aforesaid closer, production well. At this stage, accordingly, petroleum is being produced via two wells, injection fluid is introduced into the formation via the injection well and the injection fluid produced from the formation with or without petroleum via the production well closer to the injection well is returned to the formation via the injection well.

Referring now to the drawing which schematically illustrates a practice of this invention and which also illustrates the advantages obtainable, there are illustrated areal sweep patterns such as are obtainable and observed in secondary recovery operations. More particularly, in FIG. 1 of the drawing I represents an injection well and P_1 and P_2 represent production wells. Line **10** represents the sweep pattern obtained in a secondary recovery operation wherein injection fluid, such as water, is introduced in a petroleum-producing formation via injection well I and production of petroleum is car-

ried out at production well P_1 at breakthrough of the injection fluid at production well P_1. Line **11** delineates the areal sweep pattern obtained in a secondary recovery operation involving the injection of injection fluid such as water via injection well I into a petroleum-producing formation, the formation having been produced via production well P_1 until the injection fluid (water) breaks through at production well P_1 whereupon production well P_1 was shut in and petroleum production commenced via production well P_2 until breakthrough and production of injection fluid at production well P_2.

Line **12** of FIG. 2 of the drawing delineates the areal sweep pattern obtainable in a secondary recovery operation in accordance with the practice of this invention wherein injection fluid is introduced via injection well I and petroleum is produced via production well P_1, production of petroleum being maintained via production well P_1 until breakthrough of injection fluid is experienced at production well P_1. When breakthrough of injection fluid (water) is experienced at production well P_1 the production of petroleum is commenced via production well P_2 while at the same time maintaining production via production well P_1; production is maintained at production well P_2 while maintaining production via production well P_1 until breakthrough of injection fluid is experienced at production well P_2. Line **12** delineates and illustrates the areal sweep pattern of the injection fluid at substantially the moment of breakthrough of injection fluid at production well P_2. It is readily seen that the area encompassed within line **12** is much greater than the area encompassed within line **11** and is indicative of an improved secondary recovery operation and the displacement and recovery of an additional amount of petroleum from the petroleum-producing formation being produced.

Further indicative of the advantages obtainable in the practice of this invention tests were carried out with respect to increasing the efficiency of a secondary recovery operation, particularly with respect to increasing the amount of petroleum recovered during the secondary recovery operation; the amount of petroleum recoverable being indicated by the area or volume of the formation swept by the injection fluid employed. In test No. 1 carried out in a laboratory model simulating a petroleum-producing formation undergoing a secondary recovery operation and involving a point of fluid injection and a point of fluid production, point **1** is representative of an injection well and two other points **2** and **3**, in-line with and on the same side of point **1**, are representative of corresponding production wells, fluid having been injected at point **1** and fluid produced at points **2** and **3** until breakthrough of injection fluid was experienced at point **2**. Production of fluid was then discontinued at point **2** and the injection rate at point **1** was reduced to half of that previously employed and production at point **3** continued until breakthrough of injection fluid was experienced. This series of operations set forth in connection with test No. 1 is generally employed in a secondary recovery operation involving in combination an injection well and two in-line production wells.

In test No. 2 on the same laboratory model fluid was injected at point **1** and production was carried out only at point **3** until injection fluid breakthrough was experienced there.

In test No. 3 on the same laboratory model fluid was injected at point **1** and fluid was produced at points **2** and **3** until breakthrough of injection fluid was experienced at point **3**.

In test No. 4 on the same laboratory model fluid was injected at point **1** and fluid was produced at point **3** until injection fluid was observed to reach point **2** at which time production from point **2**, along with production from point **3**, was commenced until breakthrough of injection fluid was experienced at point **3**. The results of these tests are set forth hereinbelow in accompanying Table No. I.

Table No. I

Test No.	Volume swept by injection fluid	Percent increase in volume swept over Test No. 1
1	818	0
2	1,038	26.9
3	1,482	81.2
4	1,463	78.8

It is seen as a result of the foregoing tests that an increased amount of petroleum is recoverable in a secondary recovery operation carried out in accordance with this invention due to the larger areal and volume displacement obtainable in the practice of this invention as compared with other methods, including those generally employed in a secondary recovery operation.

In other laboratory tests carried out to demonstrate the advantages obtainable in the practice of this invention and involving an injection point and two production points analogous to an injection well and two corresponding production wells, respectively, in a secondary recovery operation, it was observed that in the test No. 1 where fluid was introduced at the injection point and where fluid was produced at the production points and production was discontinued when the injection fluid was produced at the production point closer to the injection point, and that in the test No. 3 where production from this closer production point was maintained while at the same time continuously maintaining production at production point **3**, farther removed from the injection point, an increased areal sweep was obtained in this latter test No. 3 by continuously maintaining the production of fluid at the closer production point until breakthrough of injection fluid at the farther point was observed. The results of these tests are set forth in accompanying Table No. II.

Table No. II

	Test No. 1	Test No. 3
Injection Rate	100	100
Prod. #2 Rate after breakthrough	0	50
Prod. #3 Rate	100	50
Vol. Swept at End of test	V	1.81V
Vol. of Displacing Fluid Produced	0	1.36V

Although emphasis has been placed in this disclosure on the practice of this invention as directed to a secondary recovery operation, particularly employing water or other similar aqueous fluid as the injection fluid or displacement fluid, as indicated hereinabove the advantages obtainable in the practice of this invention are also realized in primary petroleum production operations wherein the petroleum-producing formation is under the influence of a water drive or gas drive or both a water and a gas drive and also in the instance of a secondary recovery operation wherein a gas, such a natural gas, is employed as the injection fluid.

As will be apparent to those skilled in the art in the light of the accompanying disclosure many changes, alterations and substitutions are possible in the practice of this invention without departing from the spirit or scope thereof.

I claim:

1. A method of producing petroleum from an underground petroleum bearing formation involving an injection well and two adjacent successive production wells, said production wells being substantially in-line with said injection well, which comprises introducing injection fluid into said formation via said injection well, producing petroleum from said formation via the production well closer to said injection well, maintaining the production of petroleum from the aforesaid production well closer

to said injection well when said injection fluid begins to appear and is produced along with petroleum via the closer production well, producing petroleum from said formation via the production well farther from said injection well, and maintaining the production of petroleum from said production well farther from said injection well until breakthrough of said injection fluid is observed thereat, meanwhile producing petroleum and said injection fluid from the aforesaid production well closer to said injection well.

2. In a secondary recovery operation for the production of petroleum from an undergound petroleum-producing formation in contact with and positioned above a water producing formation and involving a plurality of wells including an injection well and production wells wherein at least one injection well is substantially, in-line with at least two production wells positioned on one side of said injection well and wherein water is introduced into said petroleum-producing formation via said injection well so as to displace petroleum from said formation towards said production wells and wherein petroleum is produced from said formation via the production well closer to said injection well and wherein water begins to be produced with said petroleum from the aforesaid production well closer to said injection well, the improvement which comprises maintaining the production of petroleum and water from said formation via the closer production well and producing additional petroleum from said formation via the production well farther removed from said injection well than the aforesaid closer production well but substantially in line with said closer production well and said injection well until the production of water is observed thereat, meanwhile maintaining said production of petroleum and water from the aforesaid closer production well.

3. In a secondary recovery operation for the production of petroleum from an underground petroleum-producing formation in contact with and positioned beneath a gas producing formation and involving a plurality of wells including an injection well and production wells wherein at least one injection well is substantially in-line with at least two production wells positioned on one side of said injection well and wherein gas is introduced into said petroleum-producing formation via said injection well so as to displace petroleum from said formation toward said production wells and wherein petroleum is produced from said formation via the production well closer to said injection well and wherein gas beings to be produced with said petroleum from the aforesaid production well closer to said injection well, the improvement which comprises maintaining the production of petroleum and gas from said formation via the closer production well and producing additional petroleum from said formation via the production well farther removed from said injection well than the aforesaid closer production well but substantially in-line with said closer production well and said injection well until the production of gas is observed thereat, meanwhile maintaining said production of petroleum and gas from the aforesaid closer production well.

4. A method of producing petroleum from an underground petroleum-producing formation which comprises penetrating said formation with at least three wells, a first well, a second well and a third well, said second well being closer to said first well than said third well, said wells being substantially in-line and the second and third wells being on one side of said first well, injecting an extraneous fluid into said formation via said first well so as to displace petroleum from said formation toward the second and third wells, producing petroleum from said formation via said second well until an excessive amount of extraneous fluid, other than petroleum, is produced along with the produced petroleum, recovering the produced extraneous fluid and returning the same to said formation via said first well, maintaining the production of petroleum from said second well while returning the produced extraneous fluid to said formation via said first well, commencing production of petroleum from said formation via said third well, and maintaining said production of petroleum from said third well until an excessive amount of said extraneous fluid is produced therewith, meanwhile maintaining the production of petroleum and extraneous fluid from said second well.

5. A method in accordance with claim 4 wherein said extraneous fluid is an aqueous fluid.

6. A method in accordance with claim 4 wherein said extraneous fluid is a gas.

7. A method in accordance with claim 4 wherein petroleum is produced from said formation via said second well until substantially all of the fluid produced from said formation via said second well is said extraneous fluid.

8. In a secondary recovery operation for the production of petroleum from an underground petroleum-producing formation involving a plurality of wells including an injection well and production wells wherein at least one injection well is substantially in-line with at least two production wells positioned on one side of said injection well and wherein injection fluid is introduced into said petroleum-producing formation via said injection well so as to displace petroleum from said formation toward said production wells and wherein petroleum is produced from said formation via the production well closer to said injection well and wherein said injection fluid begins to be produced with said petroleum from the aforesaid production well closer to said injection well, the improvement which comprises maintaining the production of petroleum and injection fluid from said formation via the closer production well while at the same time producing additional petroleum from said formation via the production well farther removed from said injection well than the aforesaid closer production well but substantially in-line with said closer production well and said injection well until breakthrough of said injection fluid is observed thereat, said injection fluid produced via said closer production well being returned to said formation via said injection well while maintaining the production of petroleum and injection fluid from said two production wells.

9. A method of producing petroleum from an underground petroleum-producing formation which comprises penetrating said formation with at least three wells, a first well, a second well and a third well, said wells being substantially in-line and the second and third wells being on one side of said first well, injecting an extraneous fluid into said formation via said first well so as to displace petroleum from said formation toward the second and third wells, producing petroleum from said formation via said second and third wells, said second well being closer to said first well than said third well, until an excessive amount of extraneous fluid, other than petroleum, is produced along with the produced petroleum, recovering the produced extraneous fluid and returning the same to said formation via said first well and maintaining the production of petroleum from said formation via said second and third wells even through an excessive amount of extraneous fluid is produced from said formation via said second well until an excess of said extraneous fluid is produced via said third well.

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