

[72] Inventor **Maynard L. Anderson**
Dallas, Tex.
[21] Appl. No. **858,620**
[22] Filed **Sept. 17, 1969**
[45] Patented **Feb. 23, 1971**
[73] Assignee **Mobil Oil Corporation**
a corporation of New York

[54] **METHODS OF SELECTIVELY IMPROVING THE FLUID COMMUNICATION OF EARTH FORMATIONS**
10 Claims, 1 Drawing Fig.

[52] U.S. Cl. **166/252,**
166/271, 166/299
[51] Int. Cl. **E21b 43/26**
[50] Field of Search. 166/252,
271, 299, 268, 270, 245

[56] **References Cited**

UNITED STATES PATENTS			
2,390,770	12/1945	Barton et al.	166/251
2,708,876	5/1955	Nowak	166/299
2,746,551	5/1956	Mounce	166/299
3,075,463	1/1963	Eilers et al.	166/299
3,256,934	6/1966	Nabor et al.	166/252X
3,270,815	9/1966	Osborn et al.	166/299

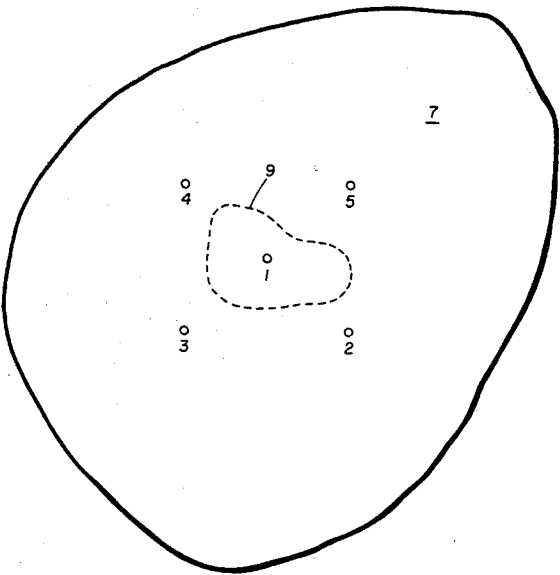
3,279,540	10/1966	Lange et al.	166/247X
3,336,982	8/1967	Woodward et al.	166/299
3,395,756	8/1968	Lange et al.	166/299
3,500,913	3/1970	Nordgren et al.	166/271X

OTHER REFERENCES

Johnson et al., " Directional Permeability Measurements And Their Significance," Producers Monthly, November 1948, pages 17—25. 166—252.

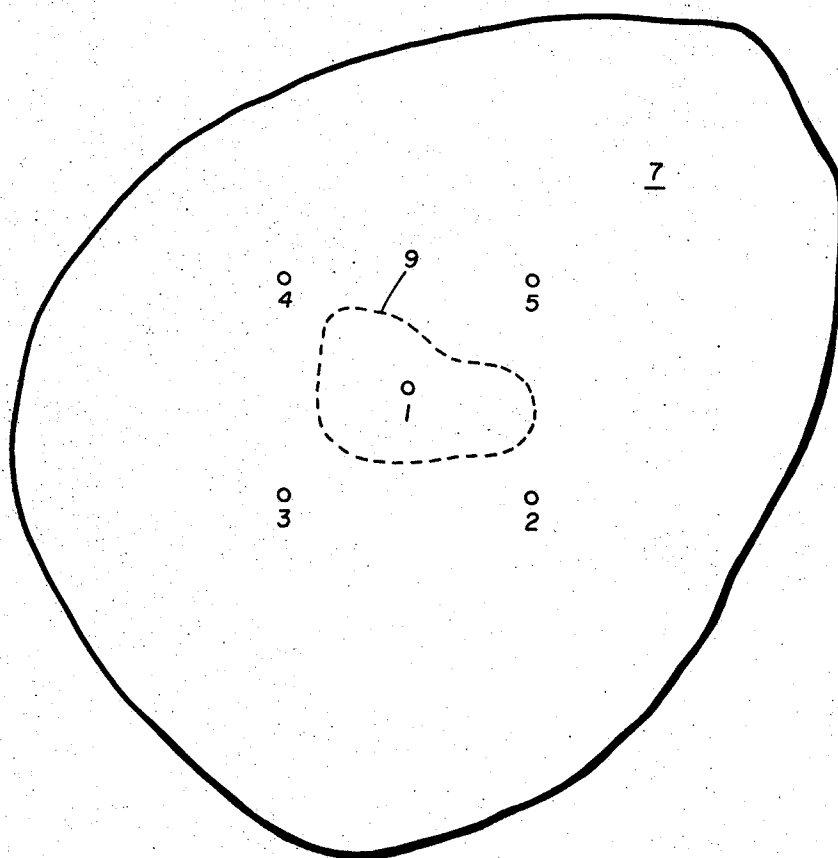
Primary Examiner—Stephen J. Novosad
Attorneys—William J. Scherback, Frederick E. Dumoulin,
William D. Jackson, Henry L. Ehrlich, Andrew L.
Gaboriault and Sidney A. Johnson

ABSTRACT: This specification discloses methods of selectively improving poor fluid communication regions of an earth formation penetrated by a pattern of injection and production wells. Liquid is injected through an injection well into the regions of permeability providing fluid communication intermediate said injection and production wells. Flow is restricted from the production wells having good fluid communication with the injection well while leaving open or unrestricted the production wells having poor fluid communication with the injection well. A fluid explosive is injected through the injection well into the regions of permeability providing poor fluid communication in the direction of the open production well. Thereafter the fluid explosive is detonated.



PATENTED FEB 23 1971

3,565,173



MAYNARD L. ANDERSON
INVENTOR

BY *W. J. K. K. K.*
ATTORNEY

METHODS OF SELECTIVELY IMPROVING THE FLUID COMMUNICATION OF EARTH FORMATIONS

BACKGROUND OF THE INVENTION

This invention relates to a process for selectively improving the permeability or fluid communication of an earth formation.

It is known in the prior art to inject liquid explosives into earth formations and then detonate them to improve the "permeability" of the formation. For example, U.S. Pat. No. 3,075,463, to Louis H. Eilers et al., discloses a method of treating a well traversing a subterranean formation which method consists essentially of injecting down the well and into the adjacent formation a mixture of two liquid reactants, one of which is an oxidizing agent and the other of which is a reducing agent. The mixture then is detonated to improve the permeability of the formation. The method may be either preceded by or followed by conventional fracturing of the formation. Another explosive fracturing technique is disclosed in U.S. Pat. No. 3,270,815, to Oliver Osborn et al. In this technique an earth formation is hydraulically fractured with a liquid hydrocarbon having particulate light metals admixed therein. Following the hydraulic fracturing step, an oxidizer solution which forms an explosive composition with the light metal particles is injected into the formation, thus displacing the hydrocarbon hydraulic fracturing fluid and forming a metallized composition in situ. This composition is then detonated thereby extending and propagating the fractures in the formation.

In U.S. Pat. No. 2,708,876 to Theodore J. Nowak, concentric rings of liquid explosive and inert liquid are alternately forced into the formation whereupon a series of annular rings alternately comprising the explosive and the inert liquid is formed about the borehole. The explosive is then detonated from within the borehole to obtain a good network for horizontal fissures throughout the area while not obtaining excessive shattering effect in the borehole.

U.S. Pat. No. 2,390,770 to Paul D. Barton et al. is concerned with controlling the combustion of an in situ oil recovery process to obtain uniformly radial progress of the combustion from the injection well toward all producing wells. Barton et al. controls the combustion to obtain uniformly radial progress by various processes, including: throttling the producing well toward which combustion is progressing more rapidly; applying additional pressure to said producing well by injecting gas into it; and injecting water through the injection well which water preferentially passes into the more permeable formations.

SUMMARY OF THE INVENTION

This invention relates to methods of selectively improving the fluid communication of an earth formation penetrated by a primary well (injection well) and a plurality of secondary wells (production wells), wherein there are regions of permeability providing good fluid communication intermediate the primary well and at least one secondary well and regions of permeability providing poor fluid communication intermediate the primary well and at least another secondary well. A liquid is injected via the primary well into the formation. Flow from secondary wells having good fluid communication with the injection well is restricted. A fluid explosive is injected via the primary well into the formation whereby it is selectively forced into the regions of permeability providing poor fluid communication intermediate the primary well and another secondary well. The explosive is then detonated, thereby selectively improving the fluid communication in the region of poor fluid communication.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a plan view of a field illustrating a 5-spot pattern utilized in accordance with the method of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing there is seen a plan view of an earth formation 7 penetrated by a 5-spot pattern made up of injection or primary well 1 and production or secondary wells 2, 3, 4, and 5. The horizontal permeability of formation 7 is heterogeneous within the area of the pattern being composed of regions of good and poor permeability (fluid communication) intermediate injection well 1 and production wells 2, 3, 4, and 5. This is indicated by dotted line 9 which represents the location of a hypothetical flood front of a flood carried out within the 5-spot pattern and is indicative of the relative permeability of the pattern. Thus, the fluid communication intermediate injection well 1 and production wells 2, 3, and 4 is about equivalent and is greater than the fluid communication intermediate injection well 1 and production well 5. This condition is undesirable since, for example, in carrying out a flood or an in situ combustion process in the pattern, formation 7 intermediate injection well 1 and production wells 2, 3, and 4 would be swept while leaving unswept a large portion of formation 7 intermediate injection well 1 and production well 5. This invention is directed toward correcting this condition by selectively improving the poor fluid communication in the region intermediate injection well 1 and production well 5 to produce more homogeneous permeability throughout the pattern.

As noted above there exist within earth formation 7 regions of good fluid communication intermediate injection well 1 and production wells 2, 3, and 4 and a region of poor fluid communication intermediate injection well 1 and production well 5. The fluid communication is provided by flow channels within the formation. These flow channels may be, for example, fractures and fissures but may also include more minute passageways through the earth formation.

In carrying out the method of this invention, a liquid is injected into earth formation 7 via injection well 1 and into the flow channels which provide fluid communication intermediate injection well 1 and production wells 2, 3, 4, and 5. Preferably liquid is injected through injection well 1 into earth formation 7 until substantial breakthrough of the liquid occurs in production wells 2, 3, and 4. In this manner flow channels intermediate injection well 1 and production wells 2, 3, and 4 are essentially filled with liquid. The flow from production wells 2, 3, and 4 which have good fluid communication with injection well 1 is then restricted, for example by throttling or choking conventional flow valves (not shown) associated with production wells 2, 3, and 4, while leaving open or unrestricted flow of production well 5 which has poor fluid communication with injection well 1. A fluid explosive, e.g., desensitized nitroglycerin, is injected via injection well 1 into formation 7. The prior injection of liquid into the flow channels and restriction of the flow from production wells 2, 3, and 4 while leaving unrestricted the flow from production well 5 serve to increase the resistance to flow of fluid explosives from injection well 1 toward production wells 2, 3, and 4. This produces a condition in formation 7 whereby the resistance to flow of fluid explosives from injection well 1 is least in the direction of production well 5. Thus, the fluid explosives are selectively forced in the direction of production well 5 and into the flow channels which provide poor fluid communication. Thereafter, the fluid explosive is detonated by conventional detonating means such as electric blasting caps to selectively improve the fluid communication in the regions of flow channels providing poor fluid communication intermediate injection well 1 and production well 5.

Flow from the desired production wells may be restricted by any suitable technique. One good technique is by throttling or choking conventional flow valves associated with the production wells. This technique offers the advantage of simplicity. However, in a preferred embodiment of the invention flow from the formation into the desired production wells is restricted by injecting liquid into these production wells. This

serves two primary purposes: (1) imposes a hydrostatic back pressure on the flow channels that provide good fluid communication and thereby restricts flow from these wells and impedes flow of fluid explosives into the flow channels that provide good fluid communication; and (2) tends to fill with liquid the flow channels that provide good fluid communication which further impedes the flow of fluid explosives thereinto.

In a further aspect of the invention the effective permeability of the formation may be determined prior to injecting liquid via injection well 1 into formation 7. This will ensure that the relative fluid communication between the respective wells is known with accuracy. Thus, in this aspect of the invention prior to injecting the liquid, gas is injected into an injection well and gas flow is measured in surrounding production wells. This information may be displayed as illustrated by dotted line 9 of the drawing to illustrate the regions of flow channels providing poor fluid communication and the regions of flow channels providing good fluid communication intermediate an injection and surrounding production wells.

The theory behind the invention of selectively improving poor fluid communication regions of an earth formation is described as follows by making reference to the drawing. Within the area of the pattern of injection and production wells of formation 7 there exists a fracture system, natural or created. This fracture system, along with any existing permeability, serves as flow channels which provide fluid communication intermediate injection well 1 and production wells 2, 3, 4, and 5. Injection of liquid into the formation tends to fill the flow channels. In the example illustrated by the drawing, regions of flow channels which provide good fluid communication exist intermediate injection well 1 and production wells 2, 3, and 4 and a region of flow channels providing poor fluid communication exists intermediate injection well 1 and production well 5. Liquid injected into formation 7 via the injection well 1 tends to preferentially fill the flow channels intermediate injection well 1 and production wells 2, 3, and 4. Prior to injecting fluid explosives into formation 7 through injection well 1, flow is restricted from production wells 2, 3, and 4 while leaving open or unrestricting flow from production well 5. Thereafter, upon injecting fluid explosive into formation 7 through injection well 1 the fluid explosive displaces the liquid from the flow channels located in the direction of open production well 5. The flow channels intermediate injection well 1 and production wells 2, 3, and 4 having liquid therein and having restriction to flow imposed at production wells 2, 3, and 4 offer a higher resistance to flow of fluid explosive injected through injection well 1 than is offered in the direction of production well 5. Thus, the fluid explosives are selectively forced into the flow channels providing poor fluid communication in the region intermediate injection well 1 and production well 5. Thereafter the fluid explosives are detonated and being thus selectively located in the poor fluid communication region intermediate injection well 1 and production well 5 selectively improves the fluid communication in this region.

A variety of liquids, e.g., water, hydrocarbons, or other liquids, may be injected into the flow channels of the formation. Ordinary care should be given however in choosing liquids which are not harmful to the formation and are inexpensive. Normally, water available in the vicinity of the pattern will prove to be satisfactory for use.

The present invention is particularly applicable in oil shale formations and more particularly in preparation of oil shale formations for carrying out in situ retorting recovery processes. Oil shale formations are very compact and offer little if any natural permeability other than some natural fractures which serve as flow channels. Therefore, it is normally necessary to fracture or rubbleize oil shale formations prior to carrying out an in situ combustion process. In order to efficiently convert kerogen existing in the formation into hydrocarbons by an in situ retorting process it is highly desirable that the resulting fluid communication between an injection

well and surrounding production wells be somewhat equalized or made uniform. This ensures that an in situ retorting process, e.g., an in situ combustion process, initiated at an injection well progresses radially toward all surrounding production wells rather than preferentially in the direction of production wells having good fluid communication with the injection well. Thus, after selecting a pattern of injection and production wells penetrating an oil shale formation having flow channels intermediate the injection and production wells a determination should be made of the relative fluid communication intermediate the injection and production wells. If a large disparity exists in the relative fluid communication of one or more injection wells as compared to the remaining production wells then the method of this invention should be followed in order to selectively improve the fluid communication in the poor fluid communication regions such that the same relative fluid communication exists between the injection well and all production wells. Thereafter an in situ retorting process may be carried out efficiently in the formation because it will propagate radially about the injection well.

In a preferred embodiment of this invention a plurality of boreholes is drilled into an oil shale formation, loaded with explosives, and detonated to form a system of flow channels. Injection and production wells are then provided in the regions of these flow channels.

It is understood of course that in selectively improving the fluid communication in poor fluid communication regions, more than one cycle of this invention may be needed. Thus, after detonating fluid explosives selectively placed, another determination of the fluid communication may be made. If there still remain regions of relatively poor fluid communication, the steps of this invention can then be repeated. It is also understood that under certain field conditions it may be desirable to utilize one or more production wells as injection wells for certain steps of this invention. Thus, for example, it may be desirable after injecting liquid into the flow channels of the formation to inject fluid explosives into the production well having relatively poor fluid communication in order to better selectively improve this poor fluid communication.

I claim:

1. A method of selectively improving the fluid communication of an earth formation penetrated by a primary well and a plurality of secondary wells, wherein there are regions of permeability providing good fluid communication intermediate said primary well and at least one secondary well and regions of permeability providing poor fluid communication intermediate said primary well and at least another of said secondary wells, comprising:

- a. injecting a liquid into said formation via said primary well;
- b. restricting flow of fluid from said formation into said at least one secondary well having good fluid communication with said primary well;
- c. concomitantly with step (b) injecting a fluid explosive via said primary well into said formation whereby said fluid explosive is selectively forced into said regions of permeability providing poor fluid communication intermediate said primary well and at least another of said secondary wells; and
- d. detonating said fluid explosive thereby selectively improving said regions of permeability providing poor fluid communication.

2. The method of claim 1 further comprising prior to step (a) injecting gas via said primary well into said formation and measuring gas flow from said secondary wells to determine the relative fluid communication intermediate said primary well and said plurality of secondary wells.

3. The method of claim 1 wherein said flow restriction of said at least one secondary well is produced by throttling a valve associated with said secondary well.

4. The method of claim 1 wherein said flow restriction of said at least one secondary well is provided by injecting liquid into said at least one secondary well.

5. A method of selectively improving the fluid communication of an oil shale formation penetrated by a primary well and a plurality of secondary wells, wherein there are regions of permeability providing good fluid communication intermediate said primary well and at least one secondary well and regions of permeability providing poor fluid communication intermediate said primary well and at least another of said secondary wells, comprising:

- a. injecting a liquid via said primary well into said formation;
- b. restricting flow of fluid from said formation into said at least one secondary well having good fluid communication with said primary well;
- c. concomitantly with step (b) injecting a fluid explosive via said primary well into said formation whereby said fluid explosive is selectively forced into said regions of permeability providing poor fluid communication in the direction of said at least another secondary well; and
- d. detonating said fluid explosive thereby selectively improving said regions of permeability providing poor fluid communication in the direction of said at least another

secondary well.

6. The method of claim 5 wherein water is injected via said primary well into said formation to fill said regions of permeability providing good fluid communication.

7. The method of claim 5 wherein said restricting flow of fluid from said formation into said at least one secondary well is produced by throttling a valve associated with said secondary well.

8. The method of claim 5 wherein said restricting flow of fluid from said formation into said at least one secondary well is provided by injecting liquid into said at least one secondary well.

9. The method of claim 5 wherein prior to step (a) there is provided a system of flow channels within said oil shale formation.

10. The method of claim 9 where said system of flow channels is provided by drilling a plurality of blast holes into said formation, loading said blast holes with explosives, and detonating said explosives in said blast holes.

25

30

35

40

45

50

55

60

65

70

75