

[54] **PETROLEUM RECOVERY PROCESS**

[75] Inventors: **Joseph C. Allen**, Bellaire; **Marc F. Fontaine**, Houston; **Alfred Brown**, Houston; **Jack F. Tate**, Houston, all of Tex.

[73] Assignee: **Texaco Inc.**, New York, N.Y.

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[58] Field of Search **166/269-275**

[56] **References Cited**

UNITED STATES PATENTS

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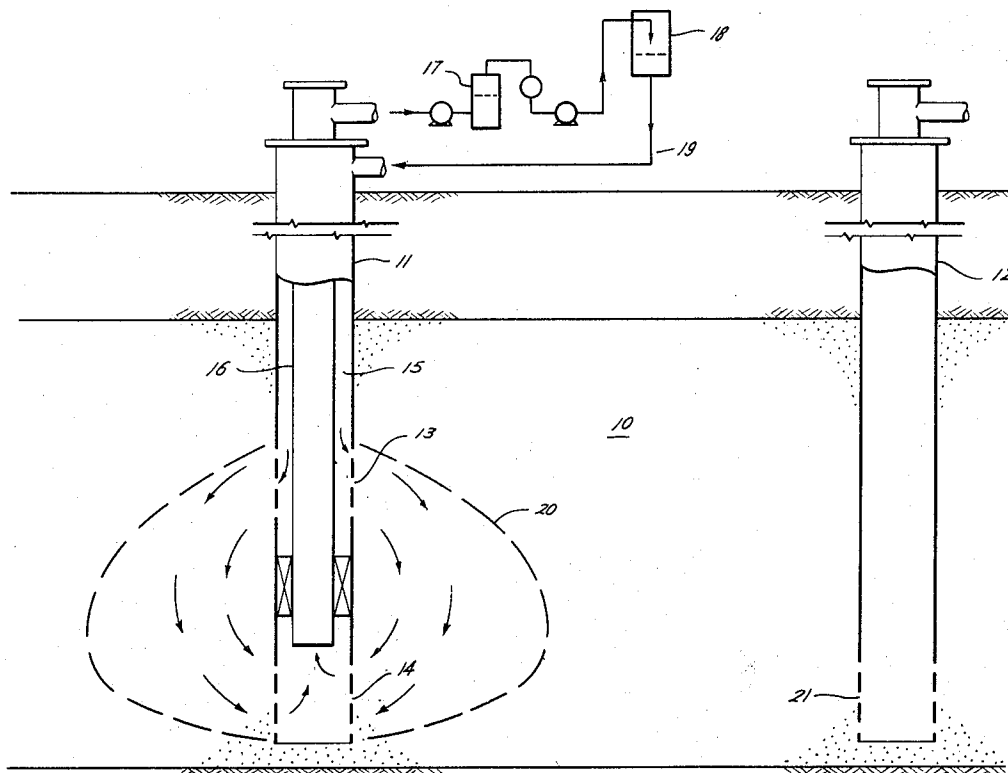
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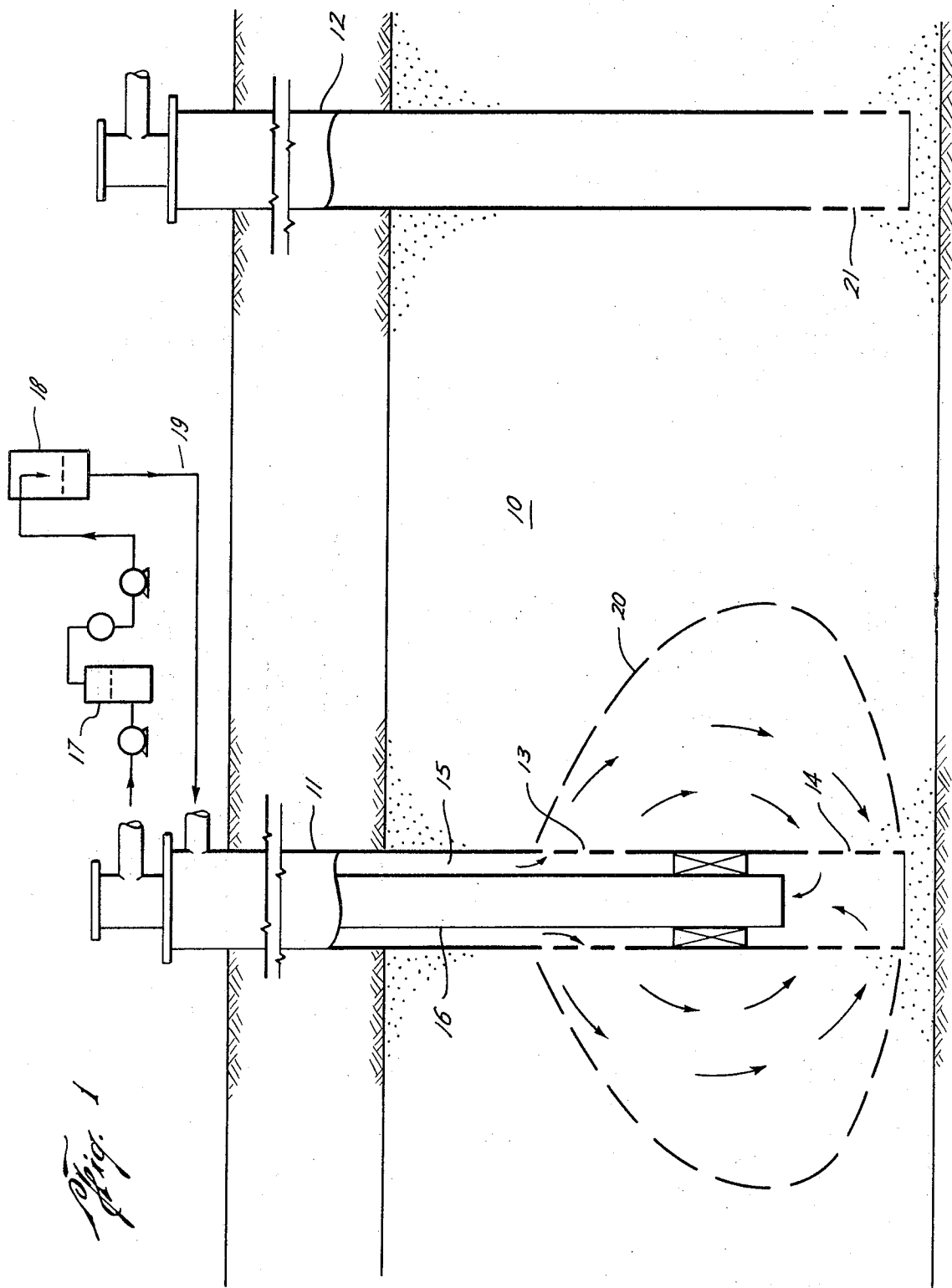
Primary Examiner—James A. Leppink
Attorney, Agent, or Firm—T. H. Whaley; C. G. Reis

[57] **ABSTRACT**

A process for producing petroleum from a subterranean reservoir is provided whereby a solvent equal in density or more dense than water is circulated between upper and lower perforations in a first well in order to dissolve petroleum in an ever-widening volume around the well bore until communication is established to a second well. At this point the production side of the first well is shut in, injection of solvent is ceased, an aqueous fluid is injected into the first well and production is taken from the second well.

12 Claims, 2 Drawing Figures





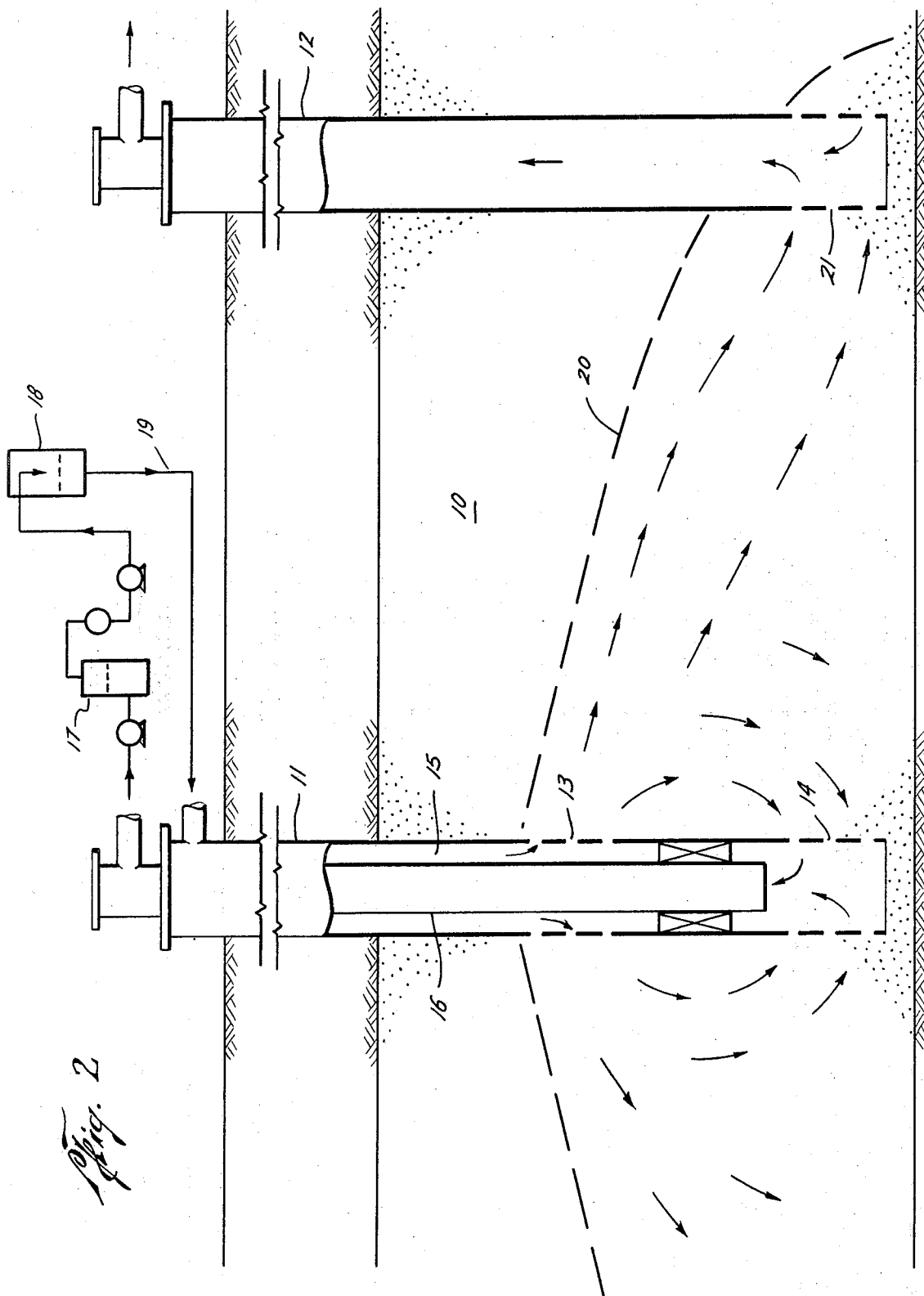


Fig. 2

PETROLEUM RECOVERY PROCESS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a process for recovering petroleum by miscible displacement.

2. Description of the Prior Art

Various methods for inducing the recovery of petroleum from underground reservoirs are in existence. These methods include injecting water, steam or some aqueous based mixture to drive the oil from the reservoir. These displacement processes are inefficient. The inefficiency of these displacement processes is partly due to the retentive forces of capillarity and interfacial tension. Miscible flooding provides a method for efficiently displacing the petroleum from a reservoir.

In miscible flooding, solvent for the petroleum is introduced into the reservoir and driven through the reservoir. Dissolution of the petroleum by the solvent permits no two phase system between the solvent and the petroleum to exist at the conditions of temperature and pressure existing in the reservoir. Therefore, the retentive forces of capillarity and interfacial tension are non-existent. These forces decrease the displacement efficiency of a recovery process where the driving fluid or displacing agent and the petroleum exist as two phases in the reservoir.

In a miscible flood process the solvent has the capability of mixing completely with the petroleum in the reservoir. A transition zone is formed at the leading edge of the solvent between the solvent and the petroleum in which miscibility exists between the solvent and the petroleum.

In displacement processes in general, the ideal sought after is piston-like displacement. That is, the displacing fluids should ideally present a flat front to the petroleum in the reservoir and displace it uniformly through the reservoir. Most miscible solvent slugs are followed by an aqueous fluid or gas to drive them through the reservoir. Moreover, most miscible solvents have heretofore been light hydrocarbons with densities less than water. Problems have arisen with such processes, however.

In a vertical miscible flood, for example, using a light hydrocarbon solvent slug followed by water, the water will tend to finger through the less dense solvent, destroying piston-like displacement and resulting in premature breakthrough of the displacing medium water. Further, there are certain petroleum deposits which are only partially soluble in the prior art solvents. One type of petroleum which is only partially soluble in prior art solvents is the tar sand oils (bitumen).

Throughout the world there are various known locations wherein the earth contains large deposits of tar sands. For example, one of the most extensive and best known deposits of this type occurs in the Athabasca district of Alberta, Canada. In the tar sands in such deposits, the oil typically has a density approaching or even greater than that of water. The Athabasca tar sands extend for many miles and occur in varying thicknesses of up to more than 200 feet. Although in some places the Athabasca tar sands are disposed practically on the surface of the earth, generally they are located under an overburden which ranges in thickness from a few feet to as much as 1,000 or more feet in depth. The tar sands located at these depths constitute one of the

world's largest presently known petroleum deposits. In these sands, the oil content ranges between about 10 percent and 20 percent by weight, although sands with lesser or greater amounts of oil content are not unusual. Additionally, the sands generally contain small amounts of water in the range of from about 1 to 10 percent by weight.

The oil present in and recoverable from Athabasca tar sands is usually a rather viscous material ranging in specific gravity from slightly below 1.00 to about 1.04 or somewhat greater. At a typical reservoir temperature, e.g., about 48°F., this oil is immobile, having a viscosity exceeding several thousand centipoises. At higher temperatures, such as temperatures above about 200°F. this oil becomes mobile, with viscosities of less than about 343 centipoises, and the tar sands are incompetent. Since this tarry material does not generally command a very high price, particularly when in its crude state, its separation and recovery must involve a minimum of expenditure in order to be economically attractive for commercial practice.

SUMMARY OF THE INVENTION

The invention is a process for producing petroleum from a subterranean reservoir having at least two wells, the first well open to the reservoir at two places vertically separated and equipped to prevent internal fluid communication between the upper and lower openings, and the second well being open to the reservoir in at least one place. The steps of the invention comprise injecting a petroleum solvent more dense than water into the reservoir through the upper openings of the first well, producing the solvent and dissolved petroleum through the lower openings of the first well until fluid communication is established between the first and second wells, producing solvent and dissolved petroleum through the second well, ceasing injection of the solvent, injecting an aqueous fluid into the upper and/or lower openings of the first well either cold or, if desired, hot enough to vaporize the solvent remaining in the reservoir and producing petroleum until the economic limit is reached.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The process of our invention may be more readily understood by referring to the attached figures and the following description.

FIG. 1 depicts the process of our invention in the early stages of operation. A hydrocarbon-bearing formation 10 is penetrated by a first well 11 and the second well 12. Well 11 has perforations at two levels in the reservoir, upper level 13 and lower level 14. Well 11 is equipped internally so as to avoid internal fluid communication between fluids entering or leaving perforations 13 and 14. A solvent heavier than water is injected through perforations 13 of well 11 via the annulus 15. The solvent, being heavier than the reservoir fluids, tends to migrate in a downward direction toward perforations 14. The solvent and the dissolved hydrocarbons are produced through tubing 16. The solvent and the dissolved petroleum is taken to the surface where the solvent and the petroleum may be separated. The separation may take place as shown in the drawing. For example, a flash unit 17 will separate the petroleum from the solvent and render the solvent into a gaseous phase which will flow into a condensation unit 18. The

condensed solvent may then be reinjected through line 19 into annulus 15 and back into the formation to form a continuous process. This is called cycling the well. The cycling process of FIG. 1 will continue until the solvent affected area of the reservoir 20 expands and comes into communication with well 12 at perforations 21.

FIG. 2 depicts a situation where the solvent-affected volume of the reservoir has reached perforations 21 of well 12. At this point there is fluid communication between well 11 and 12 and production through perforations 14 in well 11 is ceased. To conserve solvent, injection of solvent through perforations 13 is also ceased. There being sufficient solvent in the formations to dissolve additional petroleum, a hot fluid from a source 22 is injected into the annulus 15 of well 11 through perforations 13 into the reservoir. Alternatively the hot fluid could be injected into the reservoir through the lower perforations 14 of well 11 via the tubing 16 or through both perforations 13 and 14. The fluid 22 has temperature sufficient to vaporize the solvent remaining in the reservoir. The vaporized solvent will permeate the reservoir and petroleum extracted by the solvent will be produced through perforations 21 of well 12. This procedure is continued until the economic limit is reached in the production of well 12.

The types of solvents useful in the process of our invention are those which are heavier than and essentially chemically inert to water and have solubility characteristics which enable them to dissolve adequate amounts of petroleum. It is preferred that the solvent have a viscosity less than water. Ideally the solvent should be completely miscible with petroleum so that the interface between the solvent and the petroleum is removed. Examples of specific solvents include but are not limited to carbon disulfide and chlorinated hydrocarbons such as methylene chloride and carbon tetrachloride.

In certain applications carbon disulfide is the preferred solvent because of its unique properties and ease of manufacture and recovery. In the case of tar sand oil, for example, the bitumen is more soluble in carbon disulfide than in other solvents and certain bitumens may only be soluble to any appreciable extent in carbon disulfide. Also, where the recovered crude is to be catalytically treated in a refinery, for example, carbon disulfide is preferred. It is a characteristic of covalently bonded halogens such as those found in halogenated hydrocarbons that they tend to poison some refinery catalysts. Carbon disulfide does not and in addition is quite easily removed from the recovered crude by physical separation processes to be reused again leaving the crude substantially free of carbon disulfide. Carbon disulfide may also have a great economic advantage over halogenated hydrocarbons since it may be manufactured by the reaction between coke (carbon) and sulfur. Coke and sulfur are often found in excess near prolific tar sand deposits such as the Athabasca tar sands of Canada. The use of these materials would be an aid to the conservation of the environment.

The type of solvent for use in our invention will depend on the efficiency desired in dissolving of petroleum and the conditions under which the process is carried out. In general, the solvent must be heavier than water as stated before. This includes, for example, both carbon disulfide and the halogenated hydrocarbons. However, carbon disulfide is known to react with water

at certain high temperatures and using certain catalysts. This fact may tend to make the use of chlorinated hydrocarbons more attractive even though in general chlorinated hydrocarbons do not solubilize all fractions of tar sand oil. The reaction between carbon disulfide and water to yield carbonyl sulfide and hydrogen sulfide was investigated by R. R. Bacon and E. S. Boe (Industrial and Engineering Chemistry, Vol. 37, pages 469, 1945). Their results showed that the reaction did not occur in the absence of a catalyst up to 700°C. Also, the reaction did occur at temperatures as low as 200°C. in the presence of a catalyst. In addition, their work showed that the reaction was a vapor phase reaction and that the best catalyst investigated was activated alumina which obtained 100 percent conversion. Thus, in the process of our invention an important factor in considering which solvent to use will depend on the nature and temperature of the fluid following the solvent. In general, it may be safe to use steam if the temperature of the steam is below 250°F. It would appear that it would be completely safe to use hot or cold water instead of steam. Since carbon disulfide has a boiling point of 115°F., water above this temperature could be used to vaporize the carbon disulfide in the formation if such vaporization is desired. Of course, a nonaqueous fluid could be substituted for steam or hot water as the heat medium to vaporize carbon disulfide. One attractive fluid is a heavy aromatic solvent which will have its own solubilizing effect on the reservoir hydrocarbon.

It is also within the scope of our invention to use as a solvent a blend of carbon disulfide with another component, mutually soluble in carbon disulfide such as chlorinated hydrocarbons.

A very important advantage of using carbon disulfide is the lack of an emulsification between water and carbon disulfide. Water and carbon disulfide separate into distinct layers easily separable from each other. This feature is advantageous for many reasons. For example, emulsification within the formation can lead to a reduction of permeability due to what is commonly known as "emulsion blockage". The lack of emulsification when carbon disulfide is used prevents the problem from occurring. Another advantage of the lack of emulsion forming tendency between carbon disulfide and water occurs when the solvent, bitumen and water are produced and separation of the carbon disulfide from the tar sand oil or bitumen is desired. Emulsion formation would distinctly hamper these operations.

We claim:

1. A process for producing petroleum from a subterranean reservoir having at least two wells, the first well being open to the reservoir at two places vertically separated and equipped to prevent internal fluid communication between the upper and lower openings, and the second well being open to the reservoir in at least one place comprising:

- a. injecting a petroleum solvent more dense than water into the reservoir through the upper openings of the first well,
- b. producing the solvent and dissolved petroleum through the lower openings of the first well until fluid communication is established between the first and second wells,
- c. producing solvent and dissolved petroleum through the second well,
- d. ceasing injection of the solvent,

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- e. injecting an aqueous fluid into the upper openings of the first well, and
f. producing petroleum until the economic limit is reached.
2. A process as in claim 1 wherein the reservoir is a tar sand reservoir.
3. A process as in claim 2 wherein the solvent comprises carbon disulfide.
4. A process as in claim 2 wherein the solvent comprises a chlorinated hydrocarbon.
5. A process as in claim 2 wherein the solvent comprises a mixture of carbon disulfide and a chlorinated hydrocarbon.
6. A process as in claim 1 wherein the aqueous fluid of step (e) has a temperature sufficient to vaporize the solvent remaining in the reservoir.
7. A process for producing petroleum from a subterranean reservoir having at least two wells, the first well being open to the reservoir at two places vertically separated and equipped to prevent internal fluid communication between the upper and lower openings, and

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the second well being open to the reservoir in at least one place comprising :

- a. cycling a petroleum solvent more dense than water in the first well until fluid communication is established between the first and second wells,
b. injecting an aqueous fluid into the first well while petroleum is produced through the second well.
8. A process as in claim 7 wherein the reservoir is a tar sand reservoir.
9. A process as in claim 8 wherein the solvent comprises carbon disulfide.
10. A process as in claim 8 wherein the solvent comprises a chlorinated hydrocarbon.
11. A process as in claim 8 wherein the solvent comprises a mixture of carbon disulfide and a chlorinated hydrocarbon.
12. A process as in claim 7 wherein the aqueous fluid of step (b) has a temperature sufficient to vaporize the solvent remaining in the reservoir.

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