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[54] **SOLUTION MINING TECHNIQUE FOR TAR SAND DEPOSITS**

[75] Inventors: **Joseph C. Allen,** Bellaire; **Jack F. Tate,** Houston, both of Tex.

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

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[58] **Field of Search** 166/266, 267, 269, 273–275

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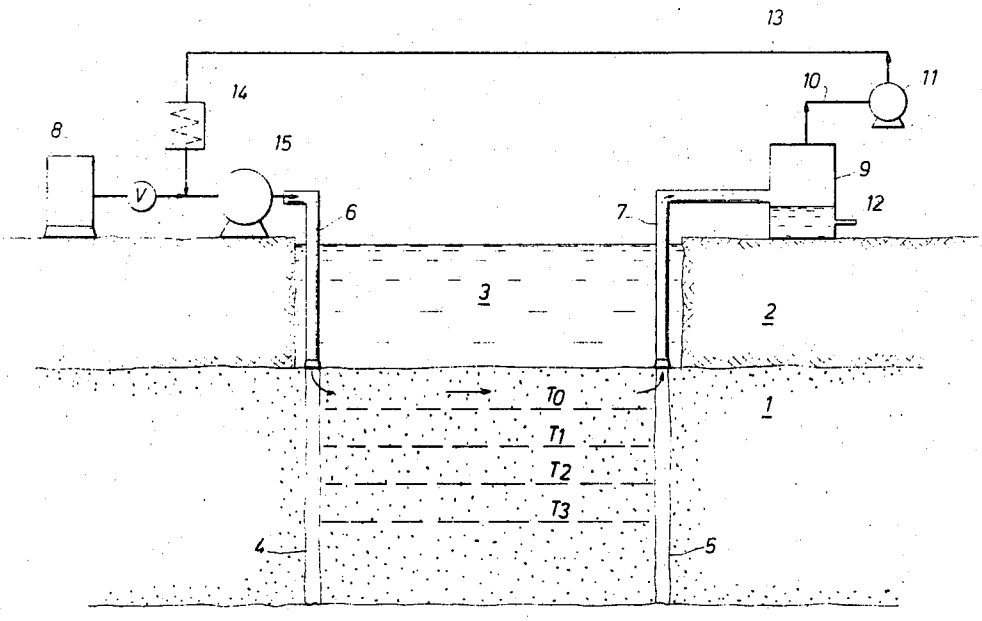
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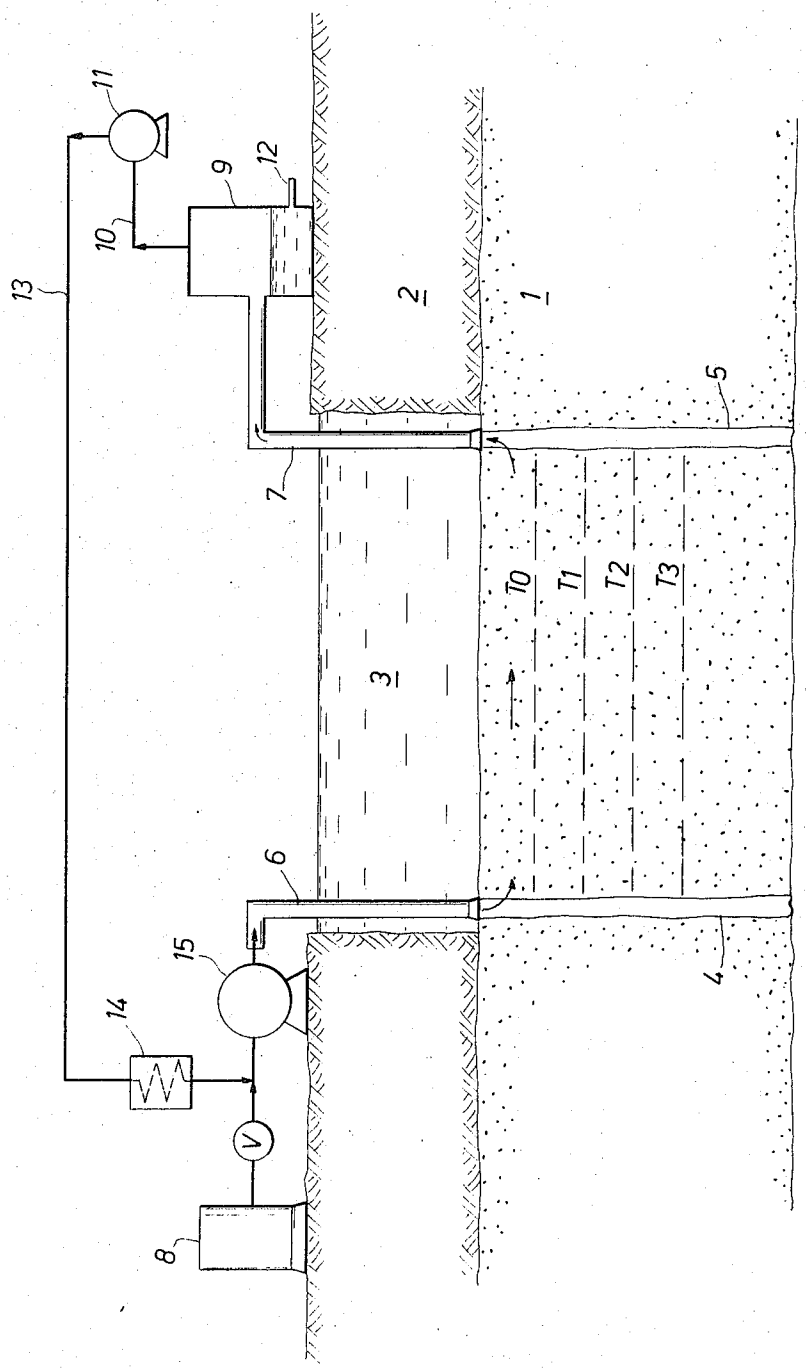
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Attorney, Agent, or Firm—T. H. Whaley; C. G. Ries

[57] **ABSTRACT**

A solution-mining technique for recovering bitumen from subterranean bitumen-containing deposits such as tar sand deposits having a ratio of overburden thickness to formation thickness of one or less. The overburden is excavated from the deposit and injection and production wells are completed open hole into the tar sand interval, and a solvent for bitumen, said solvent having a density greater than the density of water, is injected into an injection well and a mixture of solvent and bitumen is produced from the remotely located production well. The solvent moves in a horizontal direction across the top portion of the tar sand deposit. Water is used to fill the cavity above the tar sand deposit previously occupied by the overburden. The solvent remains in a thin horizontal layer between the water and the top of the tar sand deposit. As the bitumen is removed from an upper portion of the tar sand interval, water moves down to occupy the area previously occupied by bitumen, and the horizontally moving solvent layer is forced down deeper into the tar sand deposit.

16 Claims, 1 Drawing Figure




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SOLUTION MINING TECHNIQUE FOR TAR SAND DEPOSITS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to a solution-mining technique suitable for use in recovering bitumen from tar sand deposits.

2. Prior Art of the Invention

Petroleum is generally encountered in subterranean formations or reservoirs in which it has accumulated, and recovery of petroleum is achieved by penetrating these reservoirs with wells and permitting the fluid to flow to the surface as a result of natural pressure existing in the reservoir, or by pumping the fluid to the surface in instances where insufficient natural pressure exists to force it to flow to the surface. There are many petroleum-containing reservoirs which contain hydrocarbons which are much too viscous to be pumped from a reservoir under normal circumstances. When such reservoirs are encountered, production is possible only by means of some process of supplemental recovery, commonly referred to as secondary or tertiary recovery, in which energy or a solvent is supplied to the reservoir to force the petroleum to move, or a solvent is injected into the formation to reduce the viscosity of the petroleum.

The most extreme example of petroleum deposits in which petroleum viscosity prevents recovery by conventional means are the so-called tar sands or bitumen sands, such as are located in the Western United States, Western Canada, and Venezuela. These formations are known to contain enormous reserves of petroleum, but the hydrocarbons present in these formation are not recoverable by conventional techniques.

The present state of the art for the recovery of bitumen from tar sand deposits can be generally classified as strip mining and in situ separation. Strip mining requires removal of the overburden by mechanical means and the mixture of bitumen and sand is then similarly removed completely by mechanical means and transported to a surface processing plant for separation of bitumen and sand. In situ separation techniques involve separating the bitumen from the sand within the tar sand deposit itself, and only the bitumen is transported to the surface, sand being left in the tar sand deposit. Techniques presently employed for in situ separation may be generally classified as thermal or emulsification processes. The thermal techniques include in situ combustion or fire flooding, and steam flooding. Emulsification generally also involves the use of steam plus some additional chemical to promote emulsification of the high viscosity bitumen so that it may be transported to the surface.

It is generally acknowledged by persons skilled in the art that strip mining of a tar sand deposit is economical only if the ratio of overburden thickness to tar sand deposit thickness is around one or less. Even in those formations for which the overburden to formation thickness ratio is one or less, strip mining is frequently not economically feasible for a variety of reasons. Enormous quantities of material must be handled, and many of the tar sand deposits are located in regions where the climate is very hostile to both machinery and persons operating the machinery. Moreover, the density and abrasiveness of the tar sand deposit impose serious restrictions on conventional equipment used in strip mining.

In view of the foregoing, it can be appreciated that there is a substantial unfulfilled need for a process for recovering bitumen material from tar sand deposits, particularly those deposits which are relatively close to the surface, by means other than strip mining.

BRIEF DESCRIPTION OF THE DRAWING

The attached drawing is a cross-sectional view of a subterranean tar sand deposit being subjected to solution-mining in accordance with the teachings of our invention.

SUMMARY OF THE INVENTION

We have discovered, and this constitutes our invention, that subterranean tar sand deposits may be subjected to solution mining by stripping away the overburden, drilling one or more injection wells and one or more production wells remotely located from the injection wells, completing these wells open hole, and establishing fluid flow means such as by casing into the open-hole-completed injection well, and similar fluid connections with the open-hole-completed production wells. A solvent for bitumen which is denser than water is injected into the top portion of the tar sand deposit, and the void above the tar sand deposit previously occupied by the overburden is filled with water. The injected solvent moves horizontally across the top of the tar sand deposit and dissolves bitumen as it moves. A mixture of bitumen and solvent is produced from the production well. The water contained in the void immediately above the portion of the tar sand deposit being subjected to solution mining maintains the solvent in contact with the tar sand deposit, prevents evaporation of the solvent, and helps force it down into the tar sand deposit where it can dissolve bitumen more effectively. As the bitumen is extracted from the upper portions of the tar sand deposit by the horizontally moving solvent, the solvent layer moves down into previously unaffected zones of the tar sand deposit, and water moves downward to occupy the space previously occupied by the solvent and bitumen. Additional water may be added to the cavity above the tar sand deposit as necessary to keep the cavity full and to stabilize the overburden walls adjacent to the cavity. The process continues with the solvent-action zone moving downward until it has extracted essentially all of the bitumen in the tar sand deposit and water has saturated the void space previously occupied by the bitumen. Solvents suitable for use in our invention are carbon disulfide, certain halogenated hydrocarbons, carbon tetrachloride, mixtures thereof, and mixtures of such dense solvents with conventional solvents including aromatic or aliphatic hydrocarbon solvents.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

I. The Process

Our invention can best be understood by referring to the attached drawing, in which a tar sand deposit **1** is located sufficiently close to the surface that removal of the overburden is economically practical. The overburden **2** has been stripped away in the zone **3** immediately above the portion of the tar sand deposit to be subjected to the process of our invention. At least one injection well **4** and at least one production well **5** are

drilled essentially to the bottom of the tar sand deposit, and completed open hole by means of a slotted liner. The wells may also be completed using tubular goods and fluid flow communication established throughout the entire tar sand interval as by perforations. Casing **6** is set to the top of the tar sand interval to establish a communication path from the surface into the top of the well drilled in the tar sand deposit.

Similarly, casing or other fluid-conducting means **7** is set to the top of the tar sand deposit so as to establish fluid communication between the surface and the top portion of production well **5.** The solvent is supplied from container **8** on the surface, wherein it is pumped via pump **9** into the casing **6** and into the upper portion of injection well **4.** Water is added to the cavity created by removal of the overburden in zone **3.** Since the solvent has a specific gravity greater than water, it will form a horizontal layer below the water layer contained in cavity **3,** and will move horizontally toward production well **5.** Initially the solvent action will be confined to a very thin zone in the very top of the tar sand, as defined by T_o in the drawing. The injected solvent with bitumen dissolved therein is produced at production well **5** and travels to the surface via conduit **7.** Although not essential for the practice of our invention, it is desirable that the solvent also have a relatively low boiling point to facilitate surface separation from the produced crude, in order to reduce the total amount of solvent necessary for the implementation of our invention. The mixture of solvent and bitumen is thereafter passed into tank **9.** The suction **10** of compressor **11** is applied to the top of tank **9,** which may be equipped with mixing facilities and a heater and the pressure within tank **9** is reduced as a consequence thereof. The low boiling point solvent is readily removed from the mixture of bitumen and solvent, and essentially all of the solvent which was produced from the production well and passed into tank **9** is evaporated and flows via conduit **10** to compressor **11.** The bitumen with solvent removed therefrom is passed via line **12** to storage or surface processing equipment, not shown in the Figure. The compressed vaporized solvent is then flowed through line **13** to condenser **14** where it is recondensed to a liquid.

Initially, essentially all of the solvent utilized is obtained from external sources and injected into the well from tank **8.** After sufficient solvent is being produced, increasing amounts of the total solvent injected is obtained by surface separation and recondensation, and during much of the process, all of the injected solvent will be obtained from the recycling equipment.

As the horizontally moving solvent zone extracts bitumen from the upper portions of the tar sand deposit, it moves downward, contacting new portions of the tar sand deposit. With the bitumen removed from the sand, the water contained in cavity **3** moves downward to occupy the space previously occupied by bitumen. The solvent action zone will always be a relatively thin pancake shaped, horizontal zone at the interface between the water contained in cavity **3** and the tar sand deposit, but this zone will gradually move downward as the solvent depletes the tar sand deposit of bitumen. The relative times are shown along the time interfaces as T_o, T_1, T_2, T_3, etc. for the purpose of illustrating how the interface between the water contained in cavity **3** and the top of the bitumen-solvent zone changes with time. Additional water will have to be added periodically to cavity **3** in order to maintain the cavity essentially liquid full, and the total volume occupied by water will increase until eventually the solvent zone is at the very bottom of the tar sand deposit.

After the solvent zone has moved to the very bottom of the tar sand deposit, the conclusion of the operation within this particular segment of the reservoir will be indicated by a decrease in the bitumen content of the extract being produced by casing **7.** Once it is determined that the solvating zone has moved down to the very bottom of the reservoir of the deposit and the concentrating of bitumen in the extract being produced by casing **7** has declined sufficiently, the fluid being injected via casing **6** will be changed to water in order to displace the remainder of the solvent contained in the bottom of the deposit to the surface of the earth for reuse in another segment of the formation.

In exploitation of a relatively large field, it will generally be advantageous to operate with several injection wells and several production wells simultaneously. Once a segment of the field has been thus exploited, the cavity **3** can be refilled with overburden from an adjacent segment which is to be exploited next using our solution-mining technique. Since the solvent is recovered from the deposit in the final phase of the operation, maximum recycling and reuse of the solvent is possible in order to conserve the total amount of solvent necessary. Furthermore, the deposit left after conclusion of our process will be relatively clean sand saturated with water, which poses no objectionable environmental problems for future use of the area.

II. Solvent Composition

The material suitable for use as the solvent in the process of our invention can be defined as any material which has the following essential characteristics:

1. The material must be a good solvent for the particular bitumen being recovered. This is an especially demanding requirement in the instance of tar sand deposits, since there are bitumenous components of the formation fluid which are insoluble in some materials which are good solvents for conventional petroleum.

2. The material must have a specific gravity greater than the specific gravity of water so that it will remain below the water in the cavity and in the upper portion of the tar sand deposit during the solution mining operation.

3. The solvent should be essentially insoluble in and unreactive with water at the temperatures existing within the tar sand deposit during the course of the solution-mining operation.

The following additional requirements are not absolutely essential, although they are highly desirable, especially from an economic point of view:

1. The solvent should have a sufficiently low boiling point that it can be readily separated on the surface from the produced mixture of solevent and bitumen.

2. The solvent must be readily inexpensive and readily available.

One especially preferred material for use as the solvent in the solution mining technique of our invention, which satisfies essentially all of the requirements above, is carbon disulfide (CS_2). Carbon disulfide is a good solvent for essentially all hydrocarbons, and is an especially effective solvent for the asphaltic or bituminous materials encountered in viscous petroleum and tar sand deposits for which many more conventional hydrocarbon solvents are ineffective. Carbon disulfide

further meets the specific gravity requirement, since its specific gravity is 1.263, considerably greater than the specific gravity of water. Furthermore, it boils at 46.3° C., which makes it amenable to separation from the produced mixture of solvent and bitumen for recycling and reuse. Accordingly, one especially attractive embodiment of our invention involves a process carried out in a formation completed essentially as is shown in the attached Figure, wherein carbon disulfide is injected via the injection means into the top portion of the formation, travels horizontally to the remotely located production well and dissolves bitumen from the tar sand deposit as it moves. Carbon disulfide can be separated from this mixture without addition of any substantial amount of heat to the separating vessel, and the material is furthermore easily reliquefied for reinjection into the formation.

Although carbon disulfide without any additional material therein is an excellent solvent for use in the process of our invention, economic considerations may require that it be mixed with some less expensive solvent in order to reduce the total cost of the solvent. Mixtures of carbon disulfide and aliphatic or aromatic hydrocarbons may be utilized, so long as the mixture contains sufficient concentrations of carbon disulfide so that the specific gravity of the mixture is greater than one. One example of a suitable solvent mixture is a mixture of 25 percent of C_8 aliphatic hydrocarbon, or a mixture of aliphatic hydrocarbons having a specific gravity equivalent to a C_8 aliphatic hydrocarbon, and 75 percent carbon disulfide. The specific gravity of the mixture will be greater than one, which will insure that it remains below the water injected into the void volume immediately above the portion of the tar sand deposit being subjected to solution mining according to our invention. Another example would be a mixture of carbon disulfide and toluene containing at least 50 percent carbon disulfide. Mixed aromatic materials such as are frequently available from refineries may also be utilized in combination with carbon disulfide, so long as the resultant specific gravity is slightly greater than one.

Halongenated hydrocarbons or carbon tetrachloride may also be utilized as a dense solvent for the purpose of producing a solvent mixture having a specific gravity greater than one. Carbon tetrachloride, for example, has a specific gravity of 1.595, which makes it satisfactory for formulating a solvent mixture having a specific gravity greater than one. A mixture of carbon tetrachloride and approximately C_8 aliphatic hydrocarbon solvent, for example, would be a satisfactory solvent mixture for the solution-mining process of our invention so long as the mixture contained at least 50 percent carbon tetrachloride. A mixture of carbon tetrachloride nnd toluene would be similarly effective, and a slightly lower percentage of carbon tetrachloride could be tolerated and still bring the mixture within the specific gravity limitation necessary for use in the solution-mining process of our invention.

A mixture of carbon tetrachloride and carbon disulfide is another especially preferred solvent for employment in the process of our invention.

Our invention may be better understood by reference to the following field example, which is offered only as a specific illustrative embodiment of the process of our invention, and is not intended to be limitative or restrictive thereof.

III. Field Example

A tar sand deposit having 25 feet thickness of overburden and 30 feet total thickness of tar sand deposit is discovered, and the overburden thickness is excavated by mechanical means to expose the top of the tar sand deposit. An injection well is drilled to the bottom of the tar sand deposit and completed open hole, with casing set to the top of the tar sand deposit to establish essentially leak-proof fluid flow communication with the open hole injection well. A production well located a distance of 50 feet away from the injection well is similarly completed open hole, with casing connection to the surface. A mixture of 60 percent carbon disulfide and 40 percent toluene is injected into the injection well. Water is added to fill the cavity created by stripping away the overburden. A mixture of the solvent and extracts from the tar sand deposits are produced by the production well. The produced mixture is subjected on the surface to vacuum separation of the solvent mixture, and the bitumen portion of the produced extract is then sent to surface-located processing facilities. The vaporized solvent is compressed and condensed, for reinjection into the formation. As the solvent layer moves deeper into the tar sand deposit, water is continually added to the cavity in order to keep its level a few feet below the surface of the earth. This process is continued until the concentration of bitumen dissolved in the produced solvent declines noticeably, whereupon injection of solvent is terminated and water is injected into the injection well to displace the solvent to the producing well for recovery thereof for reuse in an adjacent portion of the tar sand deposit. Essentially all of the bitumen originally present within the portion of the tar sand deposit subjected to the solution-mining is recovered by this method, and recovery of solvent from the deposit is similarly essentially complete.

While our invention has been described in terms of a number of specific illustrative embodiments, it should not be considered to be so limited since many variations thereof will be apparent to persons skilled in the art without departing from the true spirit and scope of our invention. It is our desire that our invention be limited only by such restrictions and limitations as appear in the appended claims.

We claim:

1. A solution-mining method for recovering bitumen from a bitumen-containing tar sand deposit comprising:

a. removing the overburden above at least a portion of the tar sand deposit;
b. establishing injection means and production means within the tar sand deposits;
c. injecting into the top of the tar sand deposit a solvent for bitumen, said solvent having a density greater than the density of water, said solvent moving essentially horizontally across the tar sand deposit;
d. filling the cavity created by removal of the overburden with water above the solvent; and
e. removing the mixture of solvent and bitumen from the tar sand deposit from the production means.

2. A method as recited in claim 1 wherein the tar sand deposit is covered with overburden and the ratio of overburden thickness to tar sand deposit thickness is from zero to one.

3. A method as recited in claim 1 wherein the solvent for the bitumen, said solvent having a density greater than the density of water, is carbon disulfide.

4. A method as recited in claim 1 wherein the solvent for bitumen, said solvent having a density greater than the density of water, is carbon tetrachloride.

5. A method as recited in claim 1 wherein the solvent for bitumen, said solvent having a density greater than the density of water, is a halogenated hydrocarbon.

6. A method as recited in claim 1 wherein the solvent for bitumen, said solvent having a density greater than the density of water comprises a mixture of a dense solvent selected from the group consisting of carbon disulfide, carbon tetrachloride and halogenated hydrocarbons which are insoluble in and unreactive with water, and a conventional solvent for a petroleum selected from the group consisting of aliphatic and aromatic hydrocarbons.

7. A method as recited in claim 6 wherein the conventional aliphatic hydrocarbon solvent contains from 4 to 8 carbon atoms.

8. A method as recited in claim 7 wherein the aliphatic hydrocarbon solvent is butane.

9. A method as recited in claim 7 wherein the aliphatic hydrocarbon solvent is pentane.

10. A method as recited in claim 6 wherein the aromatic hydrocarbon is selected from the group consisting of benzene and toluene.

11. A method as recited in claim 10 wherein the aromatic hydrocarbon solvent is benzene.

12. A method as recited in claim 1 wherein the solvent is a mixture of carbon tetrachloride and carbon disulfide.

13. A method as recited in claim 1 further comprising the steps of subjecting the produced mixture of solvent and bitumen to vacuum separation on the surface, condensing the separated solvent and reinjecting the solvent into the tar sand deposit.

14. A method as recited in claim 1 comprising the additional step of injecting a fluid into the injection means to recover the solvent from the tar sand deposit.

15. A method as recited in claim 14 wherein the fluid is water.

16. A method for recovering bitumen from a bitumen containing subterranean tar sand deposit comprising:

a. drilling at least one injection well and at least one spaced apart production well into the tar sand deposit, said wells being in fluid communication with the tar sand deposit throughout the total thickness of the deposit;

b. removing substantially all of the overburden above at least a portion of the tar sand deposit between the injection well and production well;

c. introducing a solvent for the bitumen, the solvent density being greater than the density of water;

d. filling the cavity created by removal of the overburden with water above the solvent; and

e. removing a mixture of solvent and bitumen from the tar sand deposit by the production means.

* * * * *