

Sept. 29, 1959

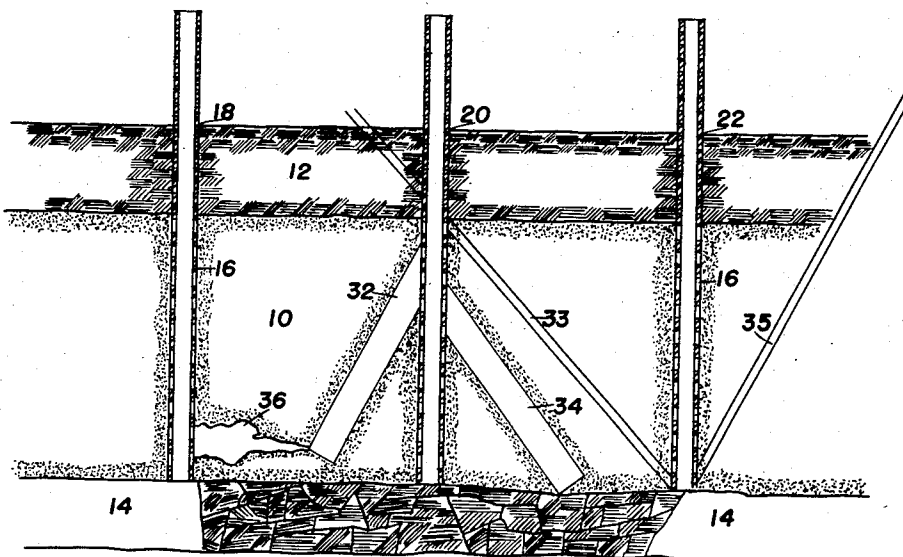
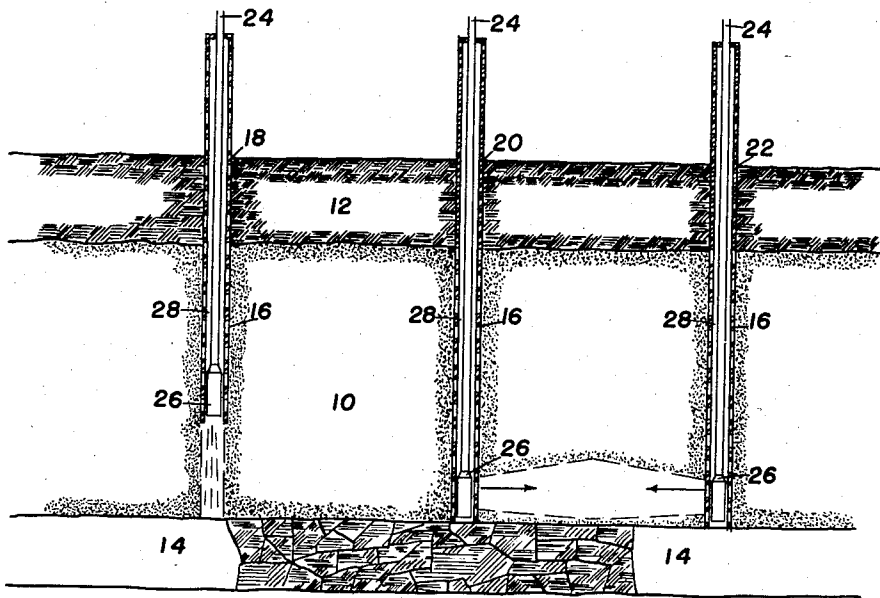
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2,906,337

METHOD OF RECOVERING BITUMEN

Filed Aug. 16, 1957

3 Sheets-Sheet 1



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2,906,337

METHOD OF RECOVERING BITUMEN

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3 Sheets-Sheet 2

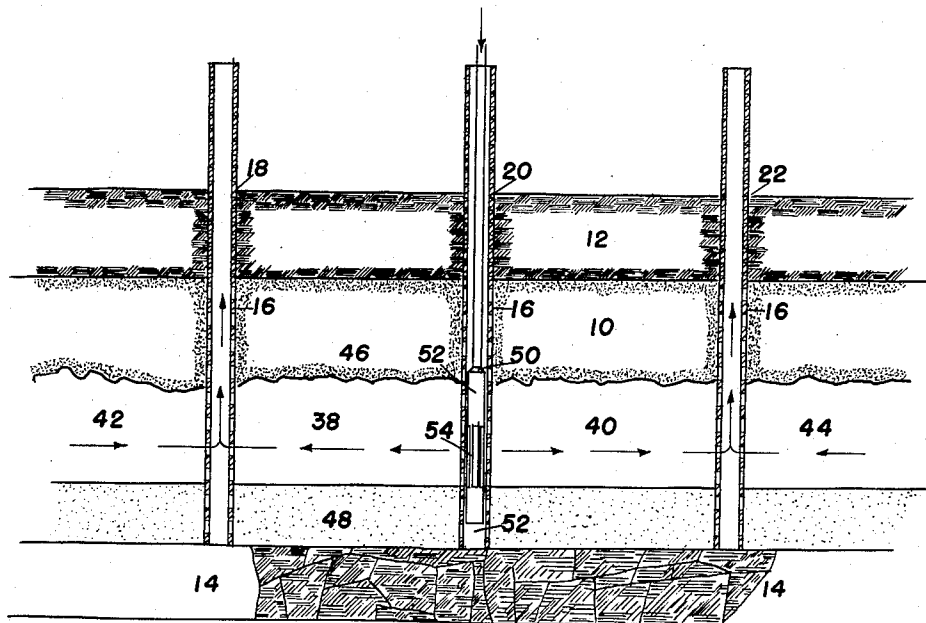


FIG. 3

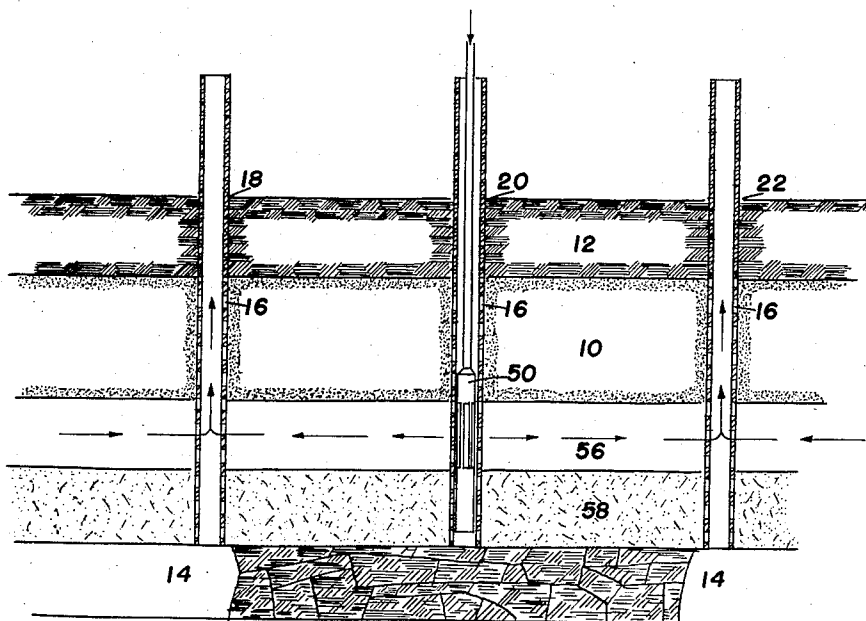


FIG. 4

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3 Sheets-Sheet 3

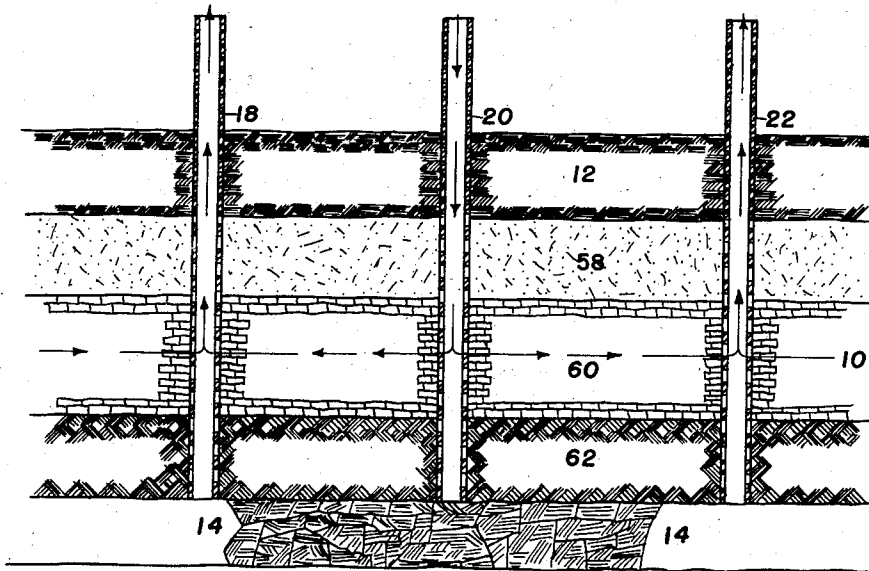


FIG. 5

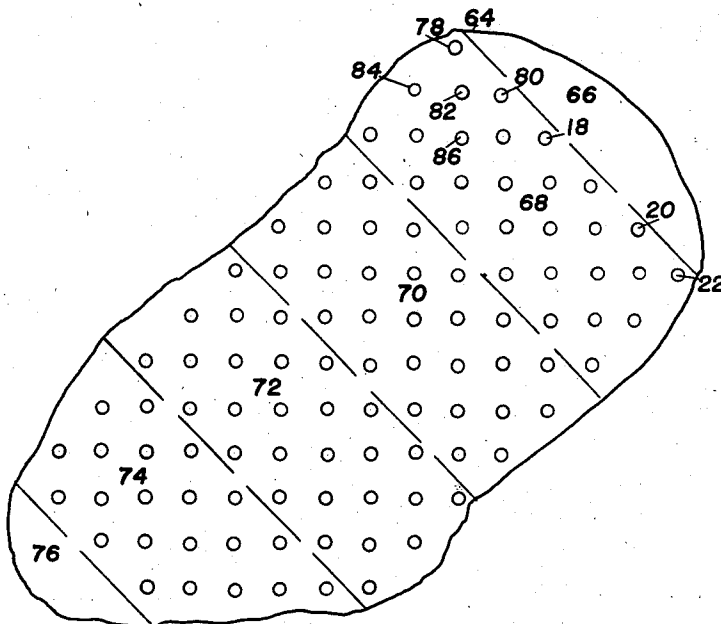


FIG. 6

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2,906,337

METHOD OF RECOVERING BITUMEN

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Application August 16, 1957, Serial No. 678,710

7 Claims. (Cl. 166—11)

This invention relates to the art of recovering oil from solid bituminous deposits, such as the Athabaska tar sands and the like.

The prior art has approached the problem of recovery of petroleum from bituminous deposits, such as tar sands, wherein the deposits are normally solid and are intermixed with sand and other aggregate, by applying numerous methods. These methods may be classified as mechanical mining, solvent treatment and heat treatment. The present invention is based on the discovery that oil can be recovered from solid bituminous deposits in a manner avoiding the difficulties attendant to mechanical mining and employing a particular sequence of steps involving drilling, heating, gravity-separation, hot gas-stripping and burning, thereby avoiding also the pitfalls of temperature control necessary for recovery of oil by burning alone. In other words, the prior art mining operations do not take into account the use of chemical reactions to fluidize and remove the oil, and the heat treatment processes do not remove a major portion of the oil by means other than heat so that the efficiency of burning can be increased. One of the main problems in connection with mining operations is the removal of the overburden, and the main problems in connection with combustion methods are starting the combustion in the solid bituminous material, controlling the temperature once combustion begins, and keeping the energy requirements low enough to make recovery profitable. This invention solves these problems by disclosing a self-sustaining process involving the application of hot vapors which cause the bitumen to become fluid and separate by gravity from the sand, which remains in place and does not have to be removed, followed by moving the point of injection of the hot vapors upwardly through the formation to further facilitate this type of separation and cover the entire depth of the deposit. Following this operation, the remaining sand, oil and organic matter are stripped with vapors at a higher temperature again from bottom to top to recover the major portion of the organic materials, bitumen and oil, and finally the formation is burned in situ and the heat recovered from this operation is utilized to form the hot fluids and gases for the preceding steps. Once begun, the process becomes self-sustaining and outside heat is required only during the initial start-up period.

Accordingly, a primary object of the invention is to provide a self-sustaining process for recovery of oil from bituminous deposits.

Another object of the invention is to provide a process for recovery of oil from bituminous deposits which has low initial energy requirements and takes advantage of differences in the density of the bitumen and the aggregate to accomplish separation.

A further object is to provide a process involving a certain sequence of steps of forming fissures, fluidizing, gravity-separating, heating, burning, and utilizing the heat from the burning steps to supply the energy for the preceding steps.

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These and other related objects will be described or become apparent as the description proceeds.

Before referring to the drawings, a general description of the invention is given whereby the relationship of the general steps of drilling and cutting, heating, stripping, burning, and heat utilization to each other and the process as a whole may be discerned.

These general steps are individually described as:

Phase I.—Drilling, channeling and fissure formation

Step 1.—A number of well bores are drilled from the earth's surface to the bottom of the bituminous deposit. The wells are preferably placed in a standard, staggered, spaced pattern with relatively close spacing therebetween, i.e., 25–30 feet. Any of the known conventional drilling methods may be used, although as a means of utilizing the energy produced in situ during the process, such methods as steam drives and hydraulic drills are especially applicable. Hydraulic drilling means, such as are used to cut through coke beds in delayed coking units, are very well adapted since they can be utilized in subsequent steps of the process. The well bores are cased as they are drilled and, as will be discussed, the initial well bores are drilled near one extremity or edge of the deposit. Directional drilling methods may be used to establish such channels as are required for the next step in the process. The directional or branch holes drilled are preferably sealed after the channels have been established.

Step 2.—After the well bores are drilled, cased and established in a spaced pattern along a segment, part, or across one end of a deposit, passageways are cut through the deposit at or near the bottom thereof by a number of methods. First of all, advantage may be taken of any natural fissures that exist. Passageways can be established by cutting or washing out the bitumen with horizontal hydraulic jets of water, steam or gas. The hydraulic jets are operated at a pressure of about 100 to 500 p.s.i.g. and the effluent therefrom is removed to the surface of the injection well. After contact is made with one or more adjacent well bores, the cuttings can be removed through the connecting well bores. Water is preferred for this step since it may be used to flush the cuttings out of the well bores. A small amount of organic matter will be recovered during this step which may be processed by known methods, such as the use of settling tanks or ponds. As alternative procedures, the channels may be established by shaped explosive charges, use of an umbrella-type whipstock and a flexible cable drill to form a horizontal bore.

Phase II.—Heating and Fluidization

Step 3.—After the establishment of the horizontal passageways throughout the pattern of well bores, some of the wells are changed to producing wells, preferably on a standard four- or five-spot pattern. Gas or steam at 400–650° F. is forced down the remaining injection wells at pressures of about 200 to 1000 p.s.i.g. Contact of the hot vapors with the sand-bitumen mixture comprising the deposit causes a portion of the bitumen to become fluid, especially that portion on the upper parts of the passageways. The fluidized bitumen is swept from the sand into the producing wells and pumped to the surface where it is separated from the gas or steam and recovered. The gas or steam is then recompressed and reheated for recycling to the injection wells.

As portions of the bitumen become fluid and are partially swept away from the passageways, the sand becomes loosened and falls to the bottom of the passageways. This process continues with a gradual lay-down of a layer of partially denuded sand, an enlargement of the passageway upwardly and horizontally, and a pro-

gressive upward movement of the main portion of the passageway.

Phase III.—Stripping

Step 4.—After the upward cycle of Phase II is completed, the bed of bituminous deposit is left in heated condition and the sand particles are loosened and partially denuded of bitumen. The loosened sand is at a temperature of about 400° to 650° F. At this point the bed of bituminous deposit is stripped with hot gas forced in at a temperature of about 900° to 1000° F. The injection is again begun at the bottom of the bed and gradually brought upward as the stripping gas is introduced. The stripping gases used in Phase III may comprise steam, hydrocarbon gases such as methane or ethane, carbon dioxide, air, or the like. The effluent mixture from this operation is carried through the bed from the injection well or wells to the producing wells.

In passing through the bituminous bed the hot stripping gases causes some vaporization, decomposition and coking of the bitumen. In addition, the stripping gases render the sand more mobile and the remaining bitumen to a fluid condition. A large proportion of the fluid bitumen is swept through the bituminous bed to the producing wells during this step, leaving the sand mixed with coke and small residual amounts of organic materials and bitumen in the deposit. The gas velocities are maintained sufficiently high during the stripping step to prevent downward draining of any liquid phases present. For this purpose, gas velocities of about 10 feet to 100 feet per second are used.

The products separated from the hot carrier gas at the surface constitute the major portion of recovered organic materials, have a low viscosity as compared with the bitumen recovered in Phase I, and may be combined with it to make a fluid which can be more readily pumped through pipelines to refineries. If further viscosity reduction is required, suitable surface facilities for this purpose may be employed.

When the injection of hot stripping gas has reached the top of the bed, heating is discontinued, and production is continued, with or without gas drive, as required, until production drops below an economical level. Pumping may be advantageous during this period.

Phase IV.—Burning

Step 5.—After the stripping step has been completed and the majority of the organic materials recovered, the remaining coke and fluid organic material are burned in situ by injecting an oxidizing medium such as air into the formation. For this purpose, preheated air at a temperature of about 700° F. to about 900° F. and a pressure of about 100 p.s.i.g. to 500 p.s.i.g. is injected. Because the bituminous bed is already at a temperature of about 900° F. to 1000° F., combustion is easily initiated merely by the introduction of an oxygen-containing atmosphere. The velocity of flow of oxygen-containing atmosphere is maintained at about 10 ft. to 100 ft. per second to insure gradual penetration of the burning zone through the formation. The combustion gases at temperatures of 1000° to 1500° F. are recovered at the producing wells and any organic vapors condensed as products. The heat is recovered from the effluent gases for use in producing steam, heating injection gases for the previous steps, and for providing power for Phases I, II and III as these phases are carried out in progression across the entire deposit. Therefore, once the first three phases have been carried out in the initial area or zone of the bituminous deposit, the entire process becomes self-sustaining and outside heat is required only during the initial period.

The invention is described in more detail in relation to the attached drawings wherein

Figure 1 is a diagrammatic representation of a vertical cross-section through the bituminous strata and ad-

jacent strata, illustrating Phase I of the process of this invention;

Figure 2 is a diagrammatic representation of a vertical cross-section through a bituminous strata and adjacent strata, illustrating the alternate step of Phase I wherein directional drilling and shaped charges are used to aid in establishing the channels through the bituminous deposit;

Figure 3 is a diagrammatic view illustrating the vertical cross-section through the bituminous strata and adjacent strata to show the progressive action of the stripping step (Phase II);

Figure 4 is a diagrammatic view illustrating the vertical cross-section through the bituminous strata and adjacent strata to show the progressive action of the stripping step and illustrate the condition of the bituminous strata as the stripping zone is gradually raised through the strata (Phase III);

Figure 5 is another diagrammatic view in vertical cross-section of the bituminous strata and adjacent strata to illustrate Phase IV, or the burning step, and the condition of the various portions of the strata during this step; and

Figure 6 is a diagrammatic layout showing the relative position of the wells drilled into the earth's surface in relation to each other, the positioning of the input and output wells, and the relationship of the several phases or steps to each other as they are carried out during the process.

The invention will now be described in relation to the drawings, giving first a general description of the component parts thereof, followed by a more detailed description in relation to the process steps.

In Figure 1 the bituminous deposit is designated at 10 lying between overburden 12 and adjacent strata 14 of the earth's surface. Casings 16 are shown placed within well bores 18, 20 and 22. The wells are cased in the usual manner, well known in the art of oil exploration and recovery. Generally perforated casings are introduced initially since perforating the casing in place may roughen the walls of the casing to a degree where the packers would not function properly. Each well is equipped with tubing 24. The tubing in well 18 is equipped with drilling means 26 which may be a rotary drill, or more preferably is a high-pressure jet arrangement whereby hot water is injected under pressure to accomplish the formation of a well bore within the bituminous deposit 10.

If the overburden 12 is consolidated, the first portion of each earth bore may be mechanically drilled, although in most instances where this type of geological formation occurs, the overburden is clay, gravel, sand, or the like which may be satisfactorily drilled by means of a hot-water jet. Once the bitumen is reached, drilling is accomplished readily by the use of a hot-water jet. The effluent from the drilling operation passes up the annulus 28 between the tubing 24 and casing 16 to a recovery system to be described.

In Figure 2, well bore 20 with directional channels 32 and 34 extending angularly into the bituminous deposit is shown in relation to well bores 18 and 22. Diagonal bore holes 33 and 35 illustrate another method of establishing communication between vertical bores. Holes 33 and 35 are drilled from the surface and communicate at the top and bottom with one or more vertical bores, as at the top of bore 20 and the bottom of earth bore 22. Such slant holes 33 and 35 are sealed at their surfaces before use. Earth bore 18 has been completed and a shaped charge exploded therein to form elongated cavity 36 to illustrate this method of starting inter-connecting passageways between the vertical earth bores.

Referring to Figure 3 wherein the progressive action of the stripping step (Phase II) is shown, the description is set forth in relation to the three completed earth bores,

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18, 20 and 22, for simplicity wherein bore 20 has been made an injection well through which steam or gas at 400°-650° F. is ejected and bores 18 and 22 are output wells. The cavity 36 and directional bores 32 and 34 have joined to form passageways 38 and 40 therebetween. Similar treatment of the previous well bores in the series will have formed passageways 42 and 44 within bituminous layer 10. This action of the steam or gas causes the caving of the bitumen as indicated at 46 and the production of a hot loose sand and bitumen layer 48 at the bottom of the passageways. The degree of caving will vary with a number of factors, but generally will be quite small. The height of passages 38 and 40 is exaggerated for clarity.

To accomplish this step, well bore 20 is equipped with a device 50 for the selective injection of fluids into geological formations. There are a number of well-known devices used in the prior art for this purpose. Since the invention does not relate to the structural features of the device 50 illustrated, it is only shown in partial detail with packers 52 and perforated or injection section 54. Prior to lowering of device 50 into earth bore 20, the entire length of casing 16 is perforated opposite the strata 10, or perforated casing is installed in the original instance. Device 50 is adapted to be lowered to the bottom of the earth bore 20, and packers 50 and 52 are actuated to seal off the bottom and top portions of the perforated area of casing 16 through which steam is to be injected into bituminous layer 10. As the action of the high pressure steam, as indicated by the arrows, passes through and extracts the bitumen, it causes the strata 10 to cave, and device 50 is gradually raised so that this treatment takes place throughout the depth of the bituminous layer 10. United States Patents 2,643,208, Ogden et al., 1,000,583 Cooper, 2,133,730 Brundred, 2,107,006 Lang, 2,611,436 Carr et al., and 1,861,332, Waitz describe apparatus of the type which may be used or are easily adapted to be used in carrying out this steam-stripping operation. Packers 52 may be mechanically operated or pressure operated.

As the injection device 50 is gradually or intermittently raised within earth bore 20, the passageways 38, 40, 42 and 44, the latter in connection with other adjacent wells, transcend the strata 10 until the overburden 12 is reached. At this point the heating and fluidization steps cease.

In Figure 4 is shown the beginning of hot-gas stripping, Phase III using wells 18, 20 and 22 as exemplary. Selective injection device 50 or its equivalent may be used for this step of the process. Injection well 20 receives hot gas at 900-1100° F. through the tubing and device 50. The gases proceed through the strata 10, forming stripping zone 56, to output wells 18 and 22, as indicated by the arrows, leaving behind a stripped coke and residual liquid area 58. The gradual movement of device 50 upwards through earth bore 20 to overburden 12 completes Phase III of the process. At this point the entire volume of strata 10 between the injection wells and output wells is left in a stripped condition leaving behind sand mixed with coke and residual liquid bitumen.

Phase IV of the process is described in connection with Figure 5, again using wells 18, 20 and 22 as illustrative. In Phase IV, the remaining coke and organic material are burned in situ by injecting air into earth bore 20 with or without the use of device 50. Controlled injection may begin at the bottom of the strata to form burning zone 60 wherein the combustion products formed spontaneously or through the use of a chemical ignitor are passed to the output wells 18 and 22, as indicated by the arrows. This leaves behind denuded sand 62. Eventually all of the strata 10 will be reduced from the coke and residual liquid-containing stage 58 to the denuded sand stage 62 throughout the depth of the strata 10.

In Figure 6 is shown one possible layout of wells

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over the earth's surface penetrating into the lower bituminous layer in the manner just described. The line 64 delineates the general outline of the horizontal boundary of the bituminous layer. The dotted lines running parallel through this outline divide the area up into the various phases of the process that have been described so far. Thus 66 is a virgin area wherein drilling and cutting will be undertaken next. Area 66 constitutes the plurality of wells, indicated by the small circles 18, 20 and 22, the complete cycle of operations of which have been described, wherein drilling and cutting operations are taking place, i.e., Figures 1 and 2 (Phase I). Area 70 constitutes the heating and fluidization (Phase II) sequence in the process (Figure 3). The stripping area described in connection with Figure 4, (Phase III) is indicated at 72. Phase IV (Figure 5) is shown by the area 74. And lastly, the denuded or depleted area is shown at 76.

For simplicity, the process has been described using three adjacent wells 18, 20 and 22 all in the same vertical plane. In actual practice, a 5-spot system is used with alternate rows of well bores in any given area 68-74 being used as output wells and the remaining rows operating as input or injection wells. The wells are preferably spaced about 25-35 feet apart, so that each injection well is served by at least four output wells and the inside pairs of output wells are shared by adjacent injection wells. This system is well known and commonly employed in secondary recovery water-flooding operations. Other known recovery systems and well-pattern spacings may be used.

The following examples are given as illustrative of the invention and various modifications will become apparent to one skilled in the art without departing from the scope of the invention.

EXAMPLE I

The drilling of a plurality of bore holes in a spaced pattern is initiated, each bore hole penetrating the overburden and extending to the bottom of the tar sand. Perforated casings are installed as the bore holes are made and the tubing is installed in those wells which are to be injection wells. A four or five spot pattern is used so that each injection well has 3 or 4 output wells adjacent thereto. The effluent from the drilling operations, formed from the injection of steam, water or gas in the form of jets at a pressure of about 250 p.s.i.g., is conveyed to a common recovery system for all of the bore holes. Recovery of any tar or hydrocarbons removed by the drilling operations for each bore hole is accomplished by settling and decantation.

Advantage is taken of any natural fissures encountered in the tar sand during the second steps of cross-channeling the adjacent bore holes. The center bore hole of a five-spot pattern may be used to initiate directional bores toward the outer bore holes. Before the tubing is inserted all the way down a bore hole, shaped charges are detonated to form elongated side fissures in the direction of the companion bore holes. A completed five-spot pattern of earth bores is illustrated in Figure 6 by earth bores 78, 80, 82, 84, and 86. During cross-channeling, if high pressure jets are used, the effluent therefrom is conveyed from the injection well to an adjacent output well and sent to the common recovery system. As soon as the cross-channeling of step 2 is completed in one five-spot pattern the drilling crew progresses to the next adjacent area and proceeds to drill a second five-spot pattern.

The first five-spot pattern is now ready for the Phase II, the heating and fluidization step 3. During this operation the injection bore 82 is equipped with a preferential packer through which gas or steam at about 500° F. is injected at about 650 p.s.i.g., bore hole 82 being operated as bore hole 20 in Figure 3 and bore holes 78, 80, 84, and 86 becoming output wells. This injection is begun at the bottom of bore hole 82 and the

point of injection is gradually raised as the tar is heated, liquified and separated from the sand granules. The effluent from this operation is passed to the settling and decanting system heretofore referred to, but not illustrated. The incoming gas or steam passing to the injection well 82 is brought to temperature and pressure by means of furnaces to initiate the heating and fluidization step. Heat exchanges are provided in the pumping-injection system so that heat from the combustion step can be used in place of the furnaces subsequently in the process. When the injection apparatus has traveled the depth of the tar sand the first five-spot pattern is ready for Phase III, the stripping step 4. During this time the second five-spot pattern of wells is completed, cross-channeled and ready for the heating and fluidization steps. Also, drilling is underway on the third five-spot pattern.

At the end of step 3 the partially denuded tar sand 58 is at a temperature of about 450° F., the injection apparatus is lowered to the bottom of the bore hole and the injection of a hot stripping gas at about 950° F. is begun. Because of the denuded condition of the tar sand, pressures in the order of 100 p.s.i.g. to 200 p.s.i.g. are sufficient to accomplish the stripping operation. The tar sand is further heated by this step and some vaporization, decomposition and coking of the bitumen occur and are initiated. The effluent is collected at the out-put bore holes 78, 80, 84, and 86 as the injection apparatus is gradually moved upwardly through injection bore hole 82, and is sent to a recovery system. Gas velocities are maintained at about 90 feet per second in order to prevent liquified bitumen from draining downwardly through the denuded sand. By starting the injection at the bottom and moving the point of injection upwardly this stripping action is made more efficient.

During this period the drilling crew is forming still another five-spot pattern of earth bores, the channeling, heating and fluidization of the second five-spot pattern is completed and the first five-spot pattern is ready for Phase IV, the burning step 5. Preheated air at a temperature of about 800° F. and a pressure of about 400 p.s.i.g. is now injected into earth bore 82 to initiate combustion of the remaining coke and heavy fluid organic material on the tar sand. This injection of air is begun at the bottom of the earth bore as in the previous steps. The reaction is exothermic and the combustion gases, at about 1400° F., are removed from earth bores 78, 80, 84 and 86 and sent through heat exchanges to act as a heating medium for the gas or steam used in step 3 and the stripping gas used in step 4 as being applied to the second and third five-spot patterns of earth bores. The maintenance of gas flow velocities of about 90 feet per second assures a vigorous reaction or combustion of the residual organic materials in the practically denuded tar sand. The injection is continued upwardly until the top of the earth bore 82 adjacent the tar sand is reached, at which time the sequence of steps as applied to the first five-spot pattern is complete.

The foregoing example is based on the carrying through of single five-spot patterns in sequence through the four phases of the present process. Another illustrative example of the invention would be to use two adjacent earth bores, one operating as an input earth bore and the other an output bore and continue the sequence of steps by treating the tar sand therebetween. Figure 6 illustrates the use of a larger pattern of earth bores, each pattern comprising a plurality of five-spot earth bores and each undergoing processing in accordance with a distinct phase of the present invention. Other systems of procedure will become apparent to one skilled in the art.

What is claimed is:

1. The process of recovering bitumen from underground formations which comprises establishing a plurality of spaced earth bores penetrating into the bituminous strata, forming passageways between the earth bores adjacent the bottom of said bituminous strata,

passing a gaseous agent into a selected one of said earth bores through said passageways at a temperature sufficient to fluidize a substantial portion of said bitumen within and above said passageways, conveying the effluent to at least one output earth bore connected therewith, moving the locale of passage of said gaseous agent upwardly in said strata until the top is reached and substantially all of said strata has been heated, recovering the bitumen from said effluent and recycling the gaseous agent to another earth bore, passing a stripping medium into said selected earth bore at a temperature sufficient to vaporize and decompose a substantial portion of said bituminous strata, advancing the passage of said stripping medium from the bottom to the top of said strata, separating bituminous products from said effluent and recycling recovered stripping medium to another input well, passing an oxidizing medium through said bituminous strata under conditions sufficient to cause in situ burning of the residual organic material, advancing the locale of passage of said oxidizing medium from the bottom to the top of said strata, and recovering heat from the effluent gases to supply the energy required for said heating and stripping steps.

2. The process of recovering bitumen from underground formations which comprises establishing a plurality of spaced earth bores penetrating into the bituminous strata, forming passageways between the earth bores adjacent the bottom of said bituminous strata, passing a gaseous agent into at least one of said earth bores through said passageways at a temperature of about 400-650° F. to fluidize a substantial portion of said bitumen within and above said passageways, conveying the effluent to at least one output earth bore connected therewith, moving the locale of passage of said gaseous agent upwardly in said strata until the top is reached and substantially all of said strata has been heated, separating the recovered bitumen from said effluent and recycling the gaseous agent to another earth bore, passing a stripping medium at a temperature of about 900-1000° F. to vaporize and decompose a substantial portion of said bituminous strata, advancing the passage of said stripping medium from the bottom to the top of said strata, separating bituminous products from said effluent and recycling recovered stripping medium, passing an oxidizing medium through said bituminous strata under conditions sufficient to cause in situ burning of the residual organic material, advancing the locale of passage of said oxidizing medium from the bottom to the top of said strata, and recovering heat from the effluent gases to supply the energy required for said heating and stripping steps.

3. The process of recovering bitumen from underground formations including a bituminous sand formation which comprises, drilling a plurality of substantially evenly spaced earth bores penetrating to the bottom of said bituminous sand, injecting a stream of a liquid washing agent under pressure horizontally from the bottom of a selected one of said earth bores in order to establish channels communicating said selected earth bore with at least one other earth bore adjacent thereto, removing the wash liquid effluent from said selected earth bore and from said interconnected adjacent earth bores, injecting a stream of a vaporous agent maintained at a temperature of about 400° to 650° F. and a pressure of about 200 to 1000 p.s.i.g. above the formation pressure into said channels at the bottom of said selected earth bore, advancing the point of injection of said vaporous agent upwardly from the bottom to the top of said bituminous sand adjacent said selected earth bore, removing the spent vaporous agent from said adjacent earth bores, injecting a stripping medium maintained at a temperature of about 900° to 1000° F. and at a velocity of about 10 to 100 feet per second into the bottom of said selected earth bore and through the partially denuded bituminous sand, advancing the point of injection of said stripping medium from the bottom to the top

of said selected earth bore, collecting the spent stripping medium from said adjacent earth bores, injecting an oxidizing medium at a temperature of about 700° to 900° F. and at a pressure of about 100 to 500 p.s.i.g. into said bituminous sand at the bottom of said selected earth bore to initiate combustion thereof, advancing the point of injection and the area of combustion within said bituminous sand upwardly to the top thereof, removing hot combustion products from the adjacent earth bores, collecting said wash liquid effluent, said spent vaporous agent and said stripping medium, recovering bitumen and hydrocarbon products therefrom, recovering heat from said hot combustion products to separately preheat said rejuvenated wash liquid, vaporous agent and said stripping medium for reuse in another group of earth bores.

4. The process of recovering bitumen from underground formations including a bituminous sand formation which comprises drilling a plurality of substantially evenly spaced earth bores penetrating to the bottom of said bituminous sand, inserting a perforated casing into said earth bores, injecting a stream of a liquid washing agent under pressure horizontally into said bituminous sand at the bottom of one group of said bore holes selected as injection bore holes and removing the effluent from the remaining bore holes operating as output bore holes whereby channels communicating therebetween are established throughout the plurality of earth bores, injecting a stream of a vaporous agent at a temperature of about 400° F. to 650° F. and a pressure of about 200 to 1000 p.s.i.g. above the formation pressure into said horizontal channels at the bottom of said injection earth bores, advancing the point of injection upwardly to the top of said bituminous sand whereby substantially the entire volume of said bituminous sand between said earth bores is heated and the bitumen therein fluidized, removing the spent vaporous agent from said output bore holes, injecting a stripping medium at a temperature of about 900° to 1000° F. at a velocity of about 10 to 100 feet per second into said heated and fluidized bituminous sand at the bottom of said injection bore holes, removing the spent stripping medium along with recovered bitumen from said output bore holes, advancing the point of injection of said stripping medium to the top of said bituminous sand whereby substantially all of the bituminous sand between said earth bores is thereby treated, injecting an oxidizing medium at a temperature of about 700° to 900° F. and a pressure of about 500 p.s.i.g. into said bituminous sand at the bottom of said injection wells, removing hot combustion products from said output bore holes, advancing the point of injection of said oxidizing medium upwardly to the top of said bituminous sand whereby substantially all of the bituminous sand between said earth bores is subjected to combustion, collecting said wash liquid effluent, said spent vaporous agent, said stripping medium, recovering bitumen and hydrocarbon products therefrom to rejuvenate same, recovering heat from said hot combustion products to separately preheat said rejuvenated wash

liquid, vaporous agent and stripping medium for reuse in another group of earth bores.

5. The process of recovering bitumen from underground formations including a bituminous sand formation extending over a given area of the earth's surface which comprises, dividing the area into a plurality of adjacent sub-areas, drilling a plurality of substantially evenly spaced bore holes in one of said sub-areas, said bore holes extending to the bottom of said bituminous sand, continuing to drill additional bore holes in the next succeeding sub-areas until all of said given area has been so treated, selecting a series of injection bore holes in said first sub-area whereby each has adjacent bore holes to function as output bore holes, continuing said selection of injection and output bore hole patterns in the next succeeding sub-areas, establishing connecting channels between said injection bore holes and each adjacent output bore hole, continuing the establishment of connecting channels between injection and output bore holes in the next succeeding sub-areas, applying the following bitumen-recovery steps to said first sub-area and each of said succeeding sub-areas in succession: (1) injecting a stream of a vaporous agent at a temperature of about 400° to 650° F. and a pressure of about 200 to 1000 p.s.i.g. into said established channels through said injection wells, advancing the point of injection of said vaporous agent upwardly until substantially the entire volume of said bituminous sand therebetween has been treated, and removing effluent vaporous agent from said output bore holes to thereby heat and fluidize said bitumen, (2) injecting a stripping medium at a temperature of about 900° to 1000° F. at the bottom of said injection bore holes, advancing the point of injection of said stripping medium upwardly until substantially the entire volume of said bituminous sand therebetween has been treated and removing spent stripping medium containing recovered bitumen from said output bore holes, (3) injecting an oxidizing medium at a temperature of about 700° to 900° F. at the bottom of said injection bore holes, advancing the point of injection of said oxidizing medium upwardly until substantially the entire volume of said bituminous sand has been burned and removing hot combustion products from said output bore holes, and recovering heat from the effluent hot combustion products to supply the heat required for said drilling, heating, and stripping steps.

6. The method in accordance with claim 4 in which the vaporous agent is steam, the stripping medium is a hydrocarbon gas and the oxidizing medium is air.

7. The method in accordance with claim 5 in which the vaporous agent is steam, the stripping medium is a hydrocarbon gas and the oxidizing medium is air.

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