Dec. 19, 1944. L. RANNEY 2,365,591

METHOD FOR PRODUCING OIL FROM VISCOUS DEPOSITS

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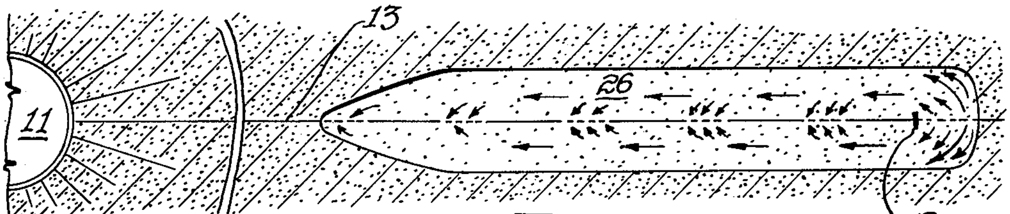

Fig. 1.

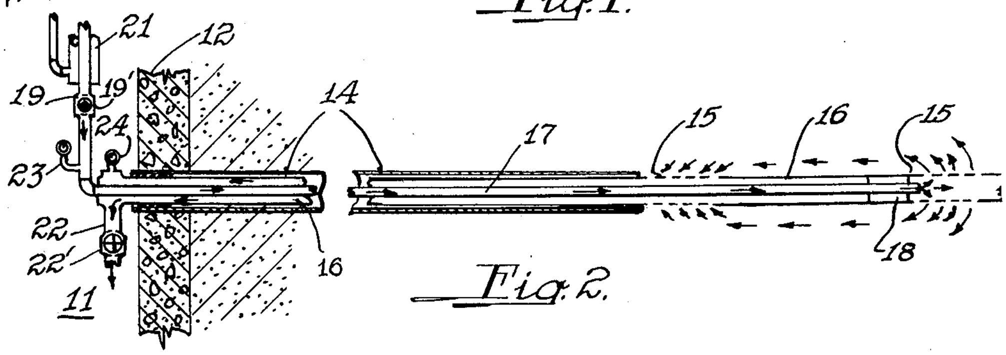

Fig. 2.

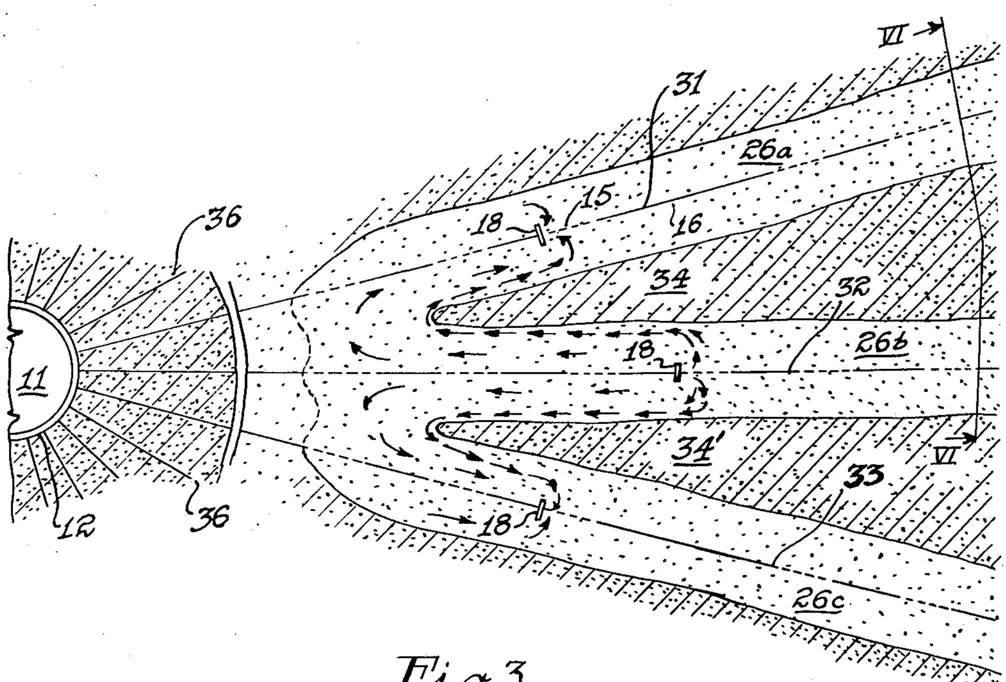

Fig. 3.

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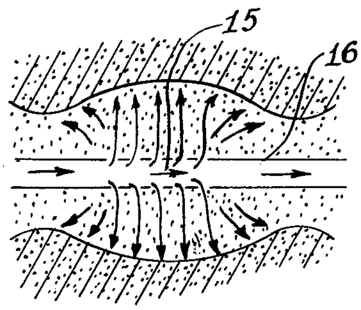

Fig. 4.

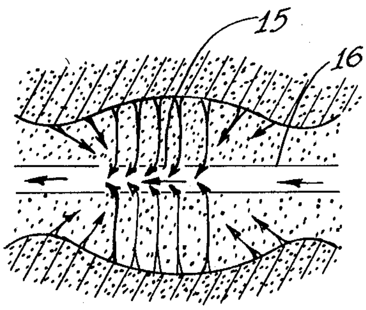

Fig. 5.

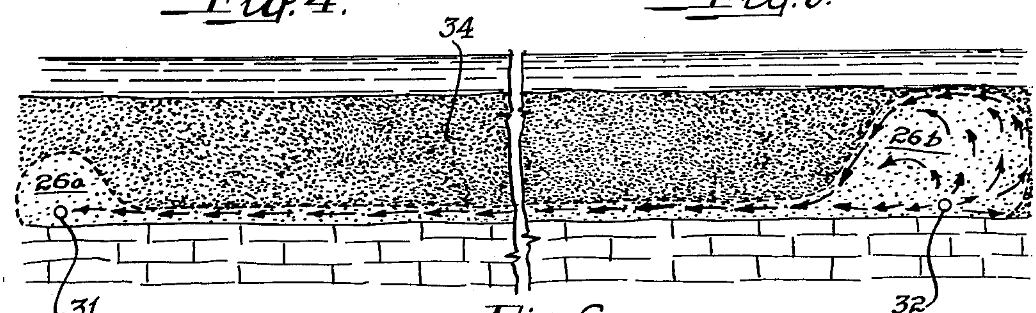

Fig. 6.

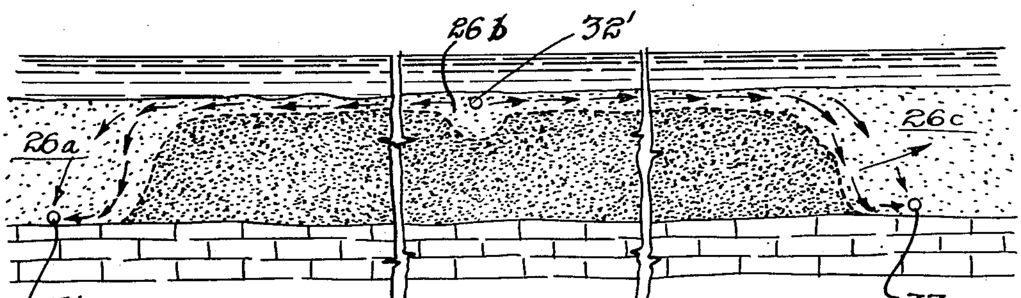

Fig. 7.

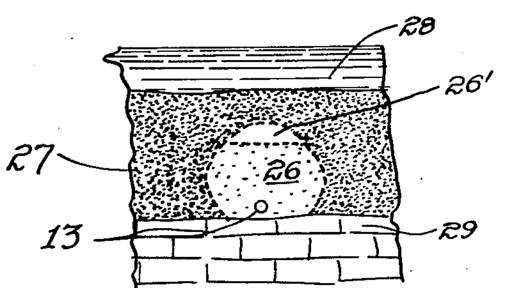

Fig. 8.

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2,365,591

METHOD FOR PRODUCING OIL FROM VISCOUS DEPOSITS

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Application August 15, 1942, Serial No. 454,956

13 Claims. (Cl. 262—1)

This invention relates generally to the recovery of oil or similar fluid mineral from earth strata, and particularly to the recovery of fluid mineral which is of such consistency that it will not flow or will not flow readily under conditions existing in the earth stratum in which it is located.

It sometimes happens that fluid minerals such as oil are so viscous that they will not flow readily and consequently will not enter a well in quantities sufficient to merit the expense of drilling a well. The oil deposits in the Alberta tar sands of Canada are an example of this. While the outcrop of this deposit is in the form of a hard asphalt, the deposit is in the form of semi-fluid oil where it is located under a few hundred feet of cover. Vertical wells have been drilled into the Alberta sand, and the drill rods and drill bits withdrawn from such wells disclose that the deposit is a heavy, thick oil at points removed from the outcrop, but too viscous to be recovered in paying quantities by ordinary well drilling operations.

An object of my invention is to provide apparatus and procedure for recovering oil by means of drilled wells from such deposits as those occurring in the Alberta tar sands.

Experience has disclosed that vertically drilled wells are ineffective in the Alberta sands. My Patent 2,280,851 of April 28, 1942, discloses apparatus and procedure for drilling horizontal wells, and one of the objects of my invention is to produce procedure, including the drilling of one or more horizontal wells, for the recovery of viscous oil such as the oil of the Alberta deposits. As disclosed by my patent, horizontal drilling procedure makes it possible to drill a well which follows the productive stratum and which therefore provides a well in which substantially the entire surface of the well is potentially a producing surface.

Horizontal wells are ordinarily drilled from a shaft which is sunk from the surface into or through the productive substratum. Such wells, however, have been drilled from outcrops and, in either case, the several hundred feet of well are located within the productive sand with the result that the entire surface of the well is a producing surface.

While a horizontal well would be far more effective than a vertically drilled well in a sand such as the Alberta tar sand, information as to the consistency of the oil in such sand makes it apparent that in order to recover the heavy viscous oil in paying quantities, something more than the mere drilling of a horizontal well must be resorted to.

While the broad object of my invention is to produce procedure for recovering heavy viscous fluid mineral from earth deposits, a specific object of my invention is to provide means for delivering a reagent into the productive sub-stratum under such conditions and in such quantities as to effectively recover all, or substantially all, of the fluid mineral located in the neighborhood of the well.

A still more specific object of the invention is to provide a procedure which involves the drilling of two or more horizontal wells and the cooperative use of such wells in the recovery of fluid mineral from the sub-stratum in which the mineral is located.

A still further object of the invention involves the positioning of horizontal wells within the productive stratum so that the recovery of the voscous fluid mineral may be effectively facilitated by the use of heat applied to the sub-stratum.

The procedure herein set forth as embodying my invention involves, in part, the drilling of a horizontal well in a sub-stratum such as the Alberta tar sand, removing fluid mineral from such sub-stratum at a point along and immediately adjacent to such well in the operation of creating a flow channel within said sub-stratum, then continuing such removal of such fluid mineral along the line of and immediately adjacent to such well by subjecting such mineral to the action of a removal reagent—such as a solvent for the fluid mineral—delivered from one portion of the well and caused to re-enter another portion of the well so that it moves through a portion of the sub-stratum in contact with fluid mineral contained therein. A further embodiment of my invention involves the drilling of at least two wells within such sub-stratum, at least one of which is a horizontal well, the creation of a flow channel in the manner described, adjacent to, and extending along each such well, the extension of one or both such flow channels until it merges with or joins the other channel, then creating a flow of a removal reagent, such as a mineral solvent, from one such well to the other while periodically varying the path of such flow through the sub-stratum by, for example, varying either the point of delivery of the reagent into the mineral bearing sand of the sub-stratum, or the point at which it leaves the sub-stratum and enters a well.

In the accompanying drawings,

Figure 1 is a diagrammatic horizontal sectional view of a productive sub-stratum, and illustrates a horizontal well drilled from a shaft sunk into the sub-stratum. The associated arrows indicate a flow of solvent from the well and into the sub-stratum in the operation of removing fluid mineral from the sub-stratum, and in the incidental operation of producing a flow channel which extends along such well.

Figure 2 is a fragmental diagrammatic view on an enlarged scale, and diagrammatically illustrates a bounding wall of the shaft and some of the equipment employed in connection with a well such as is diagrammatically illustrated in Figure 1. The associated arrows indicate the path of flow of a liquid solvent delivered into the sub-stratum from the well and returned from the sub-stratum to the well.

Figure 3 is a view similar to Figure 1 except that it diagrammatically illustrates three horizontal wells drilled from a single vertical shaft, and also illustrates a merging or joining of the flow channels formed around the individual wells. The arrows associated with Figure 3 indicate a flow of solvent from one such well into both the other wells.

Figure 4 is a diagrammatic illustration of a portion of a well formed in a sub-stratum including a heavy oil, and indicates, by means of arrows, a step in the operation of initiating the formation of a flow channel within the sub-stratum and around the well.

Figure 5 is a view corresponding to Figure 4 and indicates, by means of arrows, the next successive step in an operation such as is referred to in connection with Figure 4.

Figure 6 is a diagrammatic vertical sectional view along the line **6—6** of Figure 3 and illustrates flow channels within the sub-stratum and connecting adjacent horizontal wells, and the arrows associated therewith indicate the line of liquid flow from one such well to the other.

Figure 7 is a view similar to Figure 6, except that it illustrates a further step in the operation of removing a viscous fluid mineral from a productive sub-stratum.

Figure 8 is a fragmental vertical sectional view of a productive sub-stratum and illustrates one horizontal well and the formation of an open flow channel along such well, occasioned by a settling or movement of the productive sand after the fluid mineral has been removed therefrom.

A reference to my above mentioned patent will disclose that ordinarily the first step in drilling a horizontal well is to sink a shaft from the surface of the earth to or into the sub-stratum to be drilled. A work chamber, such as the chamber **11**, is then formed at the bottom of the shaft. The chamber is preferably cylindrical and it and the shaft are lined with a pressure-resisting, water-proof wall **12**, and each well drilled from the chamber **11** pierces this wall. In ordinary well drilling operations, such as described by my patent, the first fifty or one hundred feet of well drilled is provided with a casing which is grouted in so as to be held firmly in place and so as to provide a water-tight joint between it and the wall **12**.

Where the horizontal well is located in a productive sub-stratum, similar to the Alberta tar sand, I provide a well liner which extends throughout, or substantially throughout, the entire length of the well. The first hundred feet of the liner—from the work chamber **11** toward the end of the well—is imperforate but the remainder of the lining is made up of alternately arranged perforated and imperforate sections. Each perforated section may be approximately 5 feet long and is provided with a series of apertures which extends around it and throughout its entire length so as to provide free communication between the interior and the exterior of the liner. The intervening imperforate sections may be substantially longer than the perforated sections, e. g., it may be about 10 feet long.

The well may be lined at any convenient time during the drilling operation although it is desirable to case the first hundred feet of the well shortly after it is drilled. The liner is of less external diameter than the internal diameter of the casing and is introduced into the well through the casing.

In outlining procedure embodying my invention I first assumed the worst possible condition within the sub-stratum involved. That is, I assume that the pores of the mineral-bearing sand are completely filled with the heavy fluid mineral—hereinafter termed oil—and that the oil is too heavy to be moved cold through the sand, by a liquid or gaseous reagent subjected to a reasonable pressure, i. e., a pressure capable of being employed from the standpoint of conditions and equipment involved. Under such circumstances it will be apparent that the path of least resistance to the flow of a liquid or gaseous removal reagent, delivered from the well into the sub-stratum, will be along the liner of the well, i. e., through the crevices and spaces intervening between the outer surface of the liner and the inner or drilled face of the well. With this in mind I deliver a reagent from the well and into the sub-stratum under conditions such as to promote a flow from the well along the line of least resistance and then back into the well. I also continue such flow in progressively increasing quantities and under such conditions as to wash and scrub a gradually increasing volume of sand, and in this way dissolve or otherwise remove the oil within the sand pores and provide a relatively free flow channel within the sand itself, from the point of delivery of the reagent into the sub-stratum to an adjacent perforated section **15** of the well liner.

In Figure 1 I have diagrammatically illustrated a horizontal well **13** in which a portion of the well liner is made up of alternately arranged perforated and imperforate sections. The figure also illustrates a flow channel **26** which has been produced within the saturated sand by successive deliveries of solvent from the well into the sand and under such conditions that oil has been removed from a substantial portion of the sand immediately around the well, thus leaving the sand substantially clear of oil. I will hereinafter use the term "saturated sand" to mean sand which is filled with the heavy, tar-like oil and which, therefore, is substantially impenetrable. I will also use the term "cleared sand" to mean sand which has been freed of the heavy, viscous, impregnating oil or sand which is, at least, cleared of such oil to an extent that it provides a relatively easy path of flow for gas and a mobile liquid.

In Figure 2, the well **13** of Figure 1 is illustrated as provided with an imperforate casing **14** which extends from the mouth of the well to some point approximately one hundred feet from the wall **12** of the chamber **11**. The lining is then made up of alternately located perforated sections **15** and imperforate sections **16**. In the delivery of solvent such, for example, as kerosene or gas oil, I preferably employ an internal pipe 17 of less diameter than the internal diameter of the liner, and which extends from the work chamber 11 to a desired or predetermined position within the well.

As shown in Figure 2, the pipe 17 extends through a packer 18 located within the first imperforate section 16 and, consequently, between the first two perforated sections 15. Solvent under pressure is delivered to the pipe 17 by piping 19 which is provided with a shut-off valve 19', and it may also be provided with a heating means such as a steam jacket 21. As shown diagrammatically in Figure 2, the casing 14 is provided with a piping connection 22 which is also located in the chamber 11 and which is provided with a shut-off valve 22'.

A reagent, such as a solvent is supplied through the pipe 17 in such quantities and under such pressure that a forced flow is created through the apertures of the second perforated section 15 and into the region around the liner and back through the apertures of the first perforated section 15 of the liner, i. e. the section 15 nearest the work chamber 11. The interior of the casing 14—and consequently of that portion of the well liner back of the packer 18—is subjected to atmospheric pressure through the open valve 22'. Under some conditions it may be desirable to maintain a sub-atmospheric pressure within that portion of the well liner back of the packer 18 and around the solvent delivery pipe 17. Under conditions such as described the resulting differential pressure will cause such solvent as is delivered to the saturated sand to work its way back along the outside of the adjacent liner section 16 and enter that portion of the liner which is maintained at atmospheric or some lower pressure. In this way a flow of reagent is initiated and, as the flow continues, increased amounts of oil will be taken up by the reagent, with the result that the sand around and immediately adjacent the well will be cleared of oil and thus produce a relatively free path of flow for the reagent. As shown in Figure 1, this path will taper toward the apertures of the intake section 15 and will, therefore, approximate a cone in shape.

In some cases it may be desirable to maintain a back pressure (super-atmospheric pressure) within the portion of the liner back of the packer 18 and this may be accomplished by a proper manipulation of the valve 22' or such other equipment as may be associated with the liner.

For convenience of measuring conditions within the substratum, I may provide the piping 19, the chamber ends of the casing 14 and of the liner with pressure gages such as the gages 23 and 24. I may also provide temperature gages for each such piping. As the sand around the well is cleared of oil, the flow of reagent will progressively increase and thereby increase the scrubbing, thinning, removing and/or cutting action of the reagent on the oil of the saturated sand as a channel is cleared in that sand, with the result that a substantial volume of sand immediately adjacent the well will be converted into cleared sand.

The next step in the operation of producing a flow channel involves changing the point of delivery of reagent to the saturated sand or the point at which the solvent re-enters the well. For example, the delivery end of the pipe 17 and the associated packer 18 may be moved further away from the chamber 11. That is to say, the packer may be moved to a position such that two perforated liner sections 15 are located behind it. A flow of solvent is again created as described and the entire procedure is repeated again and again until a flow channel (cleared sand) of the desired extent is formed around the well 13. The vertical sectional view of Figure 8 illustrates this flow channel in transverse section and discloses a relationship which may exist between flow channel 26, the saturated sand 27, the overburden 28, the bedding rock 29 and a well 13. In Figure 8 I have shown a channel 26' which is free of sand or other obstruction and which will be produced in some unconsolidated sand formations by a settling of the sand grains. Such channels when so formed provide paths of reduced resistance to the flow for the reagent and where forced flow conditions are maintained they may contribute to the effectiveness of the oil removing operations.

The reagent delivered through the discharged connection 22 of the well casing 14 may be pumped to the surface of the ground and there delivered to recovery apparatus such as a simple topping still. Under some conditions, however, it may be circulated through the well and the productive sub-stratum two or more times before being delivered to the recovery apparatus.

In order to effectively remove the oil from the saturated sand during its flow through flow channels within the productive sub-stratum, the reagent must move in intimate contact with the saturated sand. Various procedures may be resorted to for accomplishing this, and in connection with Figure 3 I have outlined one such procedure. While Figure 3 is hardly more than a diagram, it indicates three wells 31, 32 and 33 drilled from a single work chamber 11. Each of the wells is illustrated as surrounded by an extent of cleared sand which, in the case of the well 31, constitutes a flow channel 26*a*. Cleared sand around the well 32 constitutes a flow channel 26*b*, and likewise, the well 33 is shown surrounded by a flow channel 26*c*. It may be assumed that each of these channels was formed by means of procedure described in connection with Figures 1 and 2. That is, each flow channel 26*a*, 26*b* and 26*c* was formed by delivering solvent under pressure to the saturated sand, by varying the point of its delivery to the saturated sand or by varying the point at which solvent so delivered reentered the well from which it was delivered, and by continuing such procedure until the three flow channels merged at a point approximately one hundred feet from the work chamber 11.

After such a juncture of flow channels is accomplished, the washing and scouring action of the solvent on the saturated sand may not only be increased by delivering solvent to the sand through one well and causing it to enter another well, but the solvent may also be so delivered that the path of normal flow through the sand will insure a highly effective scouring contact between the moving solvent and saturated sand. More generally stated, one well may be employed as the equivalent of a pressure well—from the standpoint of solvent delivery into the sub-stratum—and one or more adjacent wells may function as producing wells, and the points of delivery of solvent to, and the return of solvent from the sub-stratum may be so selected and so varied as to accomplish a highly effective utilization of the solvent.

In Figure 3 I have indicated by arrows a flow of solvent such as will result from the delivery of solvent to the well 32 where each of the wells

31 and 33 functions as a producing well. Figure 3 makes it apparent that a joining of two flow channels, such as the channels 26a and 26b, produces a peninsula-like projection 34 of saturated sand between the two adjacent and joined flow channels. A similar projection 34′ of saturated sand results from the joining of the flow channels 26b and 26c.

Under such conditions the solvent can be effectively employed in removing oil from the saturated sand if it is so delivered to the sub-stratum that the resulting stream or streams of solvent moving through the sand have an eroding action on the projections 34 and 34′.

In Figure 3 I have diagrammatically illustrated one procedural arrangement which will accomplish this result. As there indicated, a packer 18 and its associated solvent delivery pipe 17 are so located within the well 32 that the delivery of solvent to the flow channel 26b occurs at a point more remote from the chamber 11 than the tips of either of the projections 34 or 34′. Figure 3 also indicates that a pipe 17 and associated packer 18 are so located within the well 31 that the projection 34 intervenes between the two packers, i. e., the packers in the wells 31 and 32. A similar arrangement of pipe 17 and packer 18 is employed in the well 33, and here again the positioning of packer within the well 33 is such that the projection 34′ of saturated sand intervenes between it and the packer located in the well 32.

It will be understood that the pipes associated with the packers in the wells 31 and 33 function as a solvent-receiving, instead of solvent-delivery pipes, and that under such conditions the valves 22′, associated with the wells 31 and 33, are closed so that only the pipes 17 in such wells function as solvent removal means. With such an arrangement of apparatus, solvent pumped into the flow channel 26b from the well 32 tends to flow along paths of least resistance toward the two outlet pipes, i. e., the two pipes 17 located in the wells 31 and 33. The existing pressure differential which occasions such a flow of solvent may be increased by applying vacuum or sub-atmospheric pressure to piping 19 communicating with each of the wells 31 and 33. This may be readily accomplished by connecting such piping with a solvent removal apparatus such as a pump. Under the conditions described, the flow of solvent will move from the well 32 and into both of the wells 31 and 33, and a well defined stream of solvent will wash the surface of the saturated sand constituting each of the projections 34 and 34′ and thus accentuate the eroding action of the solvent on such projections or increase the rate at which each projection recedes under the action of the solvent.

It will be understood that the positions of packers 18 and of the associated pipes 17 in each of the wells 31, 32 and 33 will be changed from time to time during the procedure so as to maintain the effectiveness of the eroding action of the solvent on the oil of the saturated sand.

In Figure 6 I have illustrated by a diagrammatic sectional view along the line 6—6 of Figure 3, a condition which may exist during the operation of delivering solvent from the well 32 and employing the well 31 as a producing well. On the assumption that all portions of each of the flow channels 26a and 26b are uniformly permeable, the line of least resistance to flow will be the shortest unobstructed line between the well-liner apertures, through which solvent is delivered from the well 32, and the apertures of the liners of the well 31 which receive the solvent. It, however, will be apparent that where the wells are located at or near the bottom of the productive sub-stratum, these lines of flow will also be located at the bottom of the sub-stratum, as is illustrated in Figure 6. That is to say, the flow channels surrounding each of the wells will be adjacent the bottom of the saturated sand, and consequently the flow channel produced by the flow of solvent from, for example, the channel 26b to the channel 26a, will also be formed at the bottom of the productive sub-stratum. It, therefore, becomes necessary to employ procedure, in addition to that described in order to obtain substantially complete removal of the oil from the saturated sand.

As illustrated in Figure 6, the cleared sand or flow channel 26b, surrounding the well 32, extends to the top of the saturated sand. Such an extension of the channel may be accomplished by the delivery of hot solvent through the well 32, or by the delivery of alternate charges of hot gas and hot solvent. The heat so delivered to the cleared sand permeates the adjacent saturated sand and renders the oil less viscous. The gas itself has this effect on the oil, with the result that the oil will move downwardly into the cleared sand and thus be picked up by the flow of hot solvent as it moves through that sand. Then too, the hot gas not only imparts heat to the saturated sand but, being lighter than the oil, tends to displace the oil and thus add to the tendency of the oil to move downwardly into the previously cleared sand. The application of heat to the productive sub-stratum will reduce the viscosity of the oil immediately adjacent to the then cleared sand and will also tend to expand such gas as may be carried in solution by the oil and will in this way contribute to the erosion effect of the solvent on the oil within the saturated portion of the sand, and even though the heat applied to the oil is only effective in occasioning a slight gravity flow of the oil so heated.

It will be understood that some other procedure may be resorted to in extending the flow channel around the well 32 from the bottom to substantially the top of the productive sand. For example, the back pressure on the reagent leaving the well 32 during the initial operation of forming the channel 26b may be controlled as previously noted by the manipulation of the associated valve 22′. No matter how the flow channel 26 is extended from the bottom to the top of the sand it will be apparent that a similar procedure may be employed under conditions such as illustrated in Figure 6 and that the saturated sand of the peninsula-like projection 34 may in this way be substantially cleared of oil from the bottom to the top of the sub-stratum.

In Figure 3 I have indicated the drilling of three divergent wells from the work chamber 11. The equally spaced lines 36 radiating from the wall 12 in Figure 3, indicate that the entire sub-stratum around the work chamber 11 may be pierced by divergent wells. Procedure such as heretofore described in connection with Figures 1 and 2 may be employed in the formation of flow channels around each such well and such procedures will be so conducted that all flow channels will merge as described in connection with Figure 3.

I contemplate employing every other well as a so-called pressure well, i. e., a well from which reagent is delivered to the sub-stratum. I, therefore, contemplate employing the intervening wells as producing wells, i. e., as wells which receive the reagent so delivered after it has moved through some portion of the sub-stratum. Under such conditions, a hot reagent under pressure can be effectively employed in the recovery of oil from the saturated sand, and while conditions will vary within the productive sand, experience will indicate temperatures and pressure to be employed in connection with both a gaseous and liquid reagent, and the relative periods for delivering the same to the various pressure wells. Means such as the steam jacket **21**, illustrated in Figure 2, may be employed for heating the reagent.

A reference to Figure 6 will also disclose that under some conditions it may be desirable to from time to time convert the so-called pressure wells into producing wells, and the so-called producing wells into pressure wells. By such a procedure, more uniform flow conditions can be maintained within the sub-stratum and with relation to each of the wells, with a resulting more effective utilization of both the gas and the solvent. It will also be apparent that almost complete withdrawal of the solvent from the productive sub-stratum may be accomplished where the wells are located as disclosed in Figure 6. Gravity will contribute to a movement of the solvent toward the bottom of the sub-stratum, and gas under pressure applied through one or more of the wells will contribute to an almost complete expulsion of the solvent.

In Figure 7 I have shown an arrangement of wells which may be effectively employed where the sub-stratum of saturated sand is relatively thick and where no persistent partings exist in the sub-stratum. As there illustrated, the horizontal wells may be so drilled from the work chamber **11** that alternate wells are located at the top of the sub-stratum, i. e., at the top of the saturated sand. Where such an arrangement of wells is resorted to, the procedure outlined in connection with Figures 1 and 2 will preferably be employed in initiating the formation of the flow channels around the individual wells and in extending each individual flow channel until it joins with adjacent flow channels. For convenience of description I have assumed that the lower wells in Figure 7 correspond to the wells **31** and **33** of Figure 3, and I have so designated them in the drawings. That is to say, each of the wells **31** and **33** of Figure 7 normally functions as a producing well. The intermediate well **32'**—located in the top of the sub-stratum—corresponds to the well **32** of Figure 3, except for its position, and normally operates as a so-called pressure well.

The cleared sand or flow channel around each of the wells **31** and **33** has been extended to the top of the sand by the use of hot gas and solvent as described in connection with Figure 6. The flow channels **26***a*, **26***b* and **26***c* are shown as connected, and the procedure involved for accomplishing this is that described in connection with Figures 3 and 6, except for the fact that solvent is introduced into the top of the productive sub-stratum instead of at the bottom as there described.

After communication between the flow channels has been established, a wide variety of methods of operation is available. A liquid solvent may be introduced into the elevated well **32'** and the mixture of oil and solvent may be recovered from the wells **31** and **33** at the bottom of the sand. Gas and a solvent may be simultaneously introduced into the pressure well and under conditions such that the gas will create an appreciable fluid pressure within the cleared sand (flow channels) and thus tend to continually force the solvent against saturated sand below the flow channels. In this way the flow channel **26***b*—below the intake or pressure well **32'**—may be made relatively deep, with the result that the eroding effect of the solvent will be increased throughout the entire line of its travel from the intake well (**32'**) to the producing wells (**31** and **33**).

Under some conditions it will be found desirable to inject the gas (under pressure and preferably hot) into the intake wells, i. e., the alternate wells **32'** etc. located at the top of the productive sub-stratum. Where this is done it may also be advantageous to employ the wells at the bottom of the sand as intake wells for the solvent. Under such conditions the gas admitted to the cleared sand will have the effect of creating a gas cap within the sub-stratum, with the result that solvent moving from the intake wells (at the bottom of the sub-stratum) toward the producing wells (at the top of the sub-stratum) will be held by the cap against saturated sand and will thus be made highly effective in removing the oil from that sand. It will, of course, be understood that where the upper wells of the sub-stratum are maintained under gas pressure, as described, and at the same time employed as producing wells, the solvent will have to be introduced into the three pressure wells (at the bottom of the sub-stratum) under sufficient pressure to overcome the gas pressure as it moves out of the sand and into the producing wells at the top of the sand. It will be understood that the cap-forming gas may be introduced intermittently from the well **32**, i. e., between periods that that well operates as a producing well. This gas may be also introduced intermittently from the wells **31** and/or **32**, or it may be introduced simultaneously with the introduction of solvent or some other removal reagent.

An arrangement of wells such as illustrated in Figure 7 will also contribute to almost complete recovery of the solvent at any time during the operation. This may be accomplished by placing the wells **31**, **33** etc. at the bottom of the sub-stratum under sub-atmospheric pressure and introducing gas (preferably hot) under pressure through the wells at the top of the sub-stratum.

Figures 4 and 5 are fragmental sectional views of horizontal wells formed in oil sand which is fairly permeable but where the oil does not flow readily into the well and where it is desirable to produce flow channels and resort to the use of an oil solvent or some other recovery reagent for the purpose of speeding up the oil production. Under such conditions I may initiate the sand clearing operation without the use of packers. To accomplish this I introduce either a slug or charge of solvent or gas (both preferably heated) into the well and subject the charge to sufficient pressure to force it a short distance into the formation, i. e., into the saturated sand. This step in the procedure is indicated by the arrows associated with Figure 4. After the pressure is thus applied to the well, the well is held under pressure for a period sufficient to establish some substantial movement of the recovery reagent from the well into the sub-stratum. The pressure is then released, preferably instantaneously, and the well is allowed to produce the mixture of recovery reagent and oil. In some cases a vacuum may be applied to the well after the pressure is released. to expedite the flow from the well and also from the sand into the well. By alternately increasing and reducing pressure, as described, a type of surge is effected which will contribute to the extension of the cleared sand area around each well.

In connection with the perforated sections 15 of the liner it should be noted that each such section will preferably be fitted with a screen fine enough to prevent sand grains from moving into the well with the reagent employed. It should also be understood that in many instances I have employed the term solvent to include various removal reagents. For example, the term solvent or reagent may include within its contemplation gasoline, kerosene and other thin oils. It may also include such chemicals as carbon tetrachloride, commercial water glass (sodium silicate) and natural and other gases. In this connection it might be noted that a water solution of water glass has a high affinity for silica and that when employed as the removal reagent, has the effect of actually displacing the oil film from the individual grains of sand. It might also be noted that gas such as natural gas is ordinarily readily soluble in even viscous oil and that the use of hot gas as a reagent has the double effect of reducing the specific gravity and viscosity of the oil by reason of the delivery of heat to the oil and also by reason of its absorption by the oil. Under some conditions water, and particularly hot water, may be effectively employed as the recovery reagent in connection with a heavy viscous oil such as that of the Alberta tar sands.

For the purpose of making a distinction between a horizontal well, such as is described in my above mentioned patent, and short drilled holes such as are at times employed in mining operations, I note that a horizontal well such as is here contemplated is one in which the productive portion extends substantially parallel to the general plane or direction of the sub-stratum, and in which the ratio of length to diameter of that portion is at least 500 to 1.

Under ordinary conditions this heat employed in connection with oil recovery operations may be delivered to the sub-stratum by means of a liquid reagent at a temperature near the boiling temperature of that reagent, or by means of a superheated gas. The temperature range might therefore be noted as from slightly above earth temperature, at the level involved, to a temperature sufficient to volatilize at least some of the oil while it is in place in the productive sub-stratum. If gas is produced in any of the wells involved by any of the procedures described, such gas may be forced into an adjacent well and thus be saved for use as the oil removing reagent or for any other purpose.

Under some conditions it may be desirable to supplement the horizontal well or wells, in the productive sub-stratum, by one or more vertical wells and it will be obvious that under some circumstances the type and location of the well within the sub-stratum is not important in the carrying forward of my invention.

Various indicating devices such as thermometers, pressure gages, flow gages etc. may be employed in connection with each well liner and each liquid and gas delivery piping 19, for the purpose of observing conditions within and also at the mouth of each well. Various changes may also be made in the procedure here outlined without departing from the spirit and scope of my invention. For example, instead of first locating the packer 18 in the liner section 16 closest to the work chamber 11, as described in connection with Figures 1 and 2, the packer may be located at the far end of the well and the pressure line 17 correspondingly extended. Under such conditions the packer is successively moved toward the chamber 11 instead of away from it as described. Then too, after preliminary steps have been completed and the operation of withdrawing oil has reached the stage described in connection with Figure 6 or Figure 7, alternate wells may be employed as producing wells for a substantially long period of time, and then a reversal may be made so that the producing wells are converted into pressure wells and vice versa. This operation may also be controlled by the use of packers 18 as described in connection with Figure 3, or under some conditions packers may be removed from all wells or from only the producing wells while solvent is being delivered to the productive substratum. Variations in conditions will indicate changes in procedural steps such as are here indicated, all of which fall within the contemplation of my invention as defined by the appended claims.

What I claim is:

1. A process of removing viscous oil from the sand of a productive sub-stratum which consists in drilling two wells in such sand which diverge along length portions thereof within the sand, creating a flow channel within such sand around and along each such well, extending such channels until they merge, creating a flow of removal reagent through the merged flow channels and from one such well to the other and from time to time varying the path of such flow through such sand by varying the point of delivery of such reagent from the delivery well into such sand.

2. A method of removing oil from an oil sand which consists in drilling two horizontal wells into such sand which extend at an angle to each other within such sand, with one such well located adjacent the top and one located adjacent the bottom of said sand, creating a flow channel within said sand around each such well by introducing removal reagent into each such well and causing a flow thereof along the well within such sand and back into such well, extending such flow channels until they merge, and extending one such flow channel from the bottom to the top of said sand, and then creating a flow of reagent from a predetermined point along the length of one such well through the merged flow channels and into the other such well at a predetermined point along its length and then from time to time varying the path of flow of such reagent through such sand by varying the position along one such well of such predetermined point.

3. A method of removing oil from an oil sand, which consists in drilling two horizontal wells within such sand, one of which is located adjacent to the bottom and the other of which is located adjacent to the top of such sand, delivering a liquid removal reagent from a selected portion along the length of one such well through such sand and to a selected portion along the length of the other such well, subjecting the path of flow of such reagent through such sand and the adjacent oil within such sand to a gaseous reagent, and from time to time varying the path of such reagent by varying such selected portions of said wells.

4. A process of removing viscous oil from a productive sub-stratum which consists in drilling two wells into the productive sand of such sub-stratum which extend at an angle to each other within said sand and one of which is located near the top and the other near the bottom of such sand, forming a flow channel around each such well by creating a flow of removal reagent from one portion of each well through the sand adjacent each well and back into another portion of such well and in extending each such channel by continuing such a flow of reagent until said channels meet, then in creating a flow of a liquid reagent from a portion of one such well, through the communicating flow channels into a portion of the other such well, from time to time varying the point at which such flow of such reagent is initiated within such sand and delivering a hot gaseous reagent through one such well into such communicating flow channels.

5. A process of removing viscous oil from the oil bearing sand of a productive sub-stratum, which consists in drilling two wells into such sand which extend at an angle to each other forming a cleared sand flow channel along a portion of the length of each such well by introducing a removal reagent under pressure into each well, creating a flow of such reagent through the saturated sand of the sub-stratum from a point along such well and then back into the well, extending each such flow channel until the two channels merge and then introducing removal reagent from one well into the merged flow channels at a point remote from the point of merger, while delivering reagent from the merged flow channels into such other well at a point remote from the point of merger.

6. A process of removing viscous oil from the oil saturated sand of a productive sub-stratum, which consists in drilling two horizontal wells into such sand which diverge along at least a portion of their lengths, introducing a separate flow of removal reagent under pressure into each such well and occasioning a flow of such reagent from a predetermined point along the divergent portion of each well into the sand, through the sand parallel to the well and back into the well to create a cleared sand flow channel around and along each of such wells, then increasing the extent of the cleared sand flow channels so produced until such channels merge, then in employing one such well to deliver reagent into the merged channels from a pre-determined point along the well while employing the other well to receive reagent from the merged flow channels at a pre-determined point along the length thereof and in so locating the point of delivery of such reagent from one such well to such merged channels and the point of discharge of such reagent from such channels to the other such well that saturated sand intervenes between such points of delivery and discharge.

7. A process of removing viscous oil from oil saturated sand of a productive sub-stratum, which consists in drilling two wells into such sand which diverge along at least a portion of their lengths, introducing a removal reagent under pressure into each such well and occasioning a flow of such reagent from the well into the saturated sand and back into the well to create a cleared sand flow channel along and around divergent portions of such wells, continuing the flow of the reagent from at least one of such wells until the cleared sand flow channels merge, then employing one such well to deliver reagent from a pre-determined point along its length into the merged flow channels while employing the other well to receive reagent from the merged flow channels at a pre-determined point along the length of such well and in so locating the point of delivery of reagent from one well with relation to the point of receipt of reagent by the other such well that saturated sand intervenes between such points and from time to time so varying the point of delivery of such reagent from one such well to the merged channels and the point of receipt of such reagent by the other such well that a substantial amount of saturated sand intervenes between such points.

8. A method of recovering viscous fluid mineral from an earth stratum containing the same, which comprises drilling two wells into and along such stratum, increasing the permeability of portions of the stratum adjacent both wells by delivering a removal reagent into each such well and causing the same to flow along a portion of such well in contact with fluid mineral of the stratum, causing a flow of reagent from one well through the portions of increased permeability and into the other well while delivering a reagent such as gas into the last mentioned well.

9. A method of recovering a viscous mineral from the mineral locked grains of a productive sand, which consists in drilling a horizontal well into such sand, creating a cleared sand flow channel within such sand by introducing a removal reagent into such well and creating a flow of such reagent along a length portion thereof in contact with such mineral, drilling a second horizontal well into such sand at a different level from the first mentioned well, creating a second cleared sand, flow channel along a length portion of the second well by introducing a removal agent into such well, causing a flow of such reagent along a length portion thereof in contact with such mineral, and then introducing a gaseous medium under pressure into the higher of said flow channels while maintaining a flow of removal reagent through the other of such flow channels.

10. A method of removing oil from the oil-clogged sand of a productive sub-stratum which consists in drilling two horizontal wells into said sub-stratum which extend at an angle to each other and are located at different levels within such sand, creating a flow channel within such sand and around each such well by forcing a removal reagent into such sand from a predetermined point along the length of each well, creating a flow of such reagent along a portion of each well and through such sand by maintaining a region of reduced pressure within the well and within such sand at a point remote from the point of delivery of reagent to the sand from such well and by withdrawing from each such well the reagent entering it from the sand, then extending each such flow channel so produced until they merge and then creating a flow of such reagent from a predetermined point along the length of one such well through such merged flow channels and into the other such well while subjecting such merged flow channels to the pressure of gas delivered thereto through one such well.

11. A method of removing oil from oil-clogged sand of a productive sub-stratum, which consists in drilling two wells into said sub-stratum which extend horizontally, at an angle to each other and are located at different levels within sand, creating flow channels of increased perme-

ability within such sand adjacent each such well by delivering a removal reagent into each such well and forcing the same into the sand and along a portion of each such well, continuing such delivery and such forcing until said channels merge, then causing a removal reagent to flow from a predetermined point of one such well to the other through such merged flow channels while discharging from the receiving well the reagent entering that well and in periodically varying the path of flow of such reagent from one such well to the other by varying the point of reagent delivery to the merged flow channels.

12. A method of removing viscous fluid mineral from the mineral-bearing sand of a productive sub-stratum, which consists in entering the sub-stratum, drilling two wells into said sand and substantially parallel to the bedding planes thereof and at an angle to each other, rendering a substantial-length portion of the wall of each such well impervious to fluid flow, creating a flow of removal reagent through each such well past the impervious wall portion thereof into such sand and then back into such well to produce flow channels of increased permeability along each such well, repeating the delivery of reagent from and the return of reagent to each such well until the flow channels so formed around the separate wells merge, then creating a flow of reagent from one such well through the merged flow channels and into the other such well while discharging from the receiving well the reagent entering such well from the merged flow channels and from time to time varying the path of reagent flow from one well to the other through such merged flow channels.

13. A method of recovering viscous oil from the oil-clogged sand of a productive earth stratum, which consists in drilling two wells into the stratum which are located one above the other within such sand, forming a flow channel of increased permeability along each such well by delivering removal reagent into each such well, forcing such reagent into such sand and causing the same to re-enter such well after contact with such sand, repeating such operations until the flow channels of increased permeability around the two wells merge and then delivering a heat-carrying removal reagent to such merged channels through the upper of such wells while maintaining a flow of liquid reagent from one such well to the other through the merged flow channels.

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