Oct. 4, 1966 G. SCHLICHT ETAL 3,276,518
PROCESS FOR EXTRACTING LIQUID BITUMENS FROM AN UNDERGROUND DEPOSIT
Filed Aug. 6, 1962 2 Sheets-Sheet 1

FIG. 1

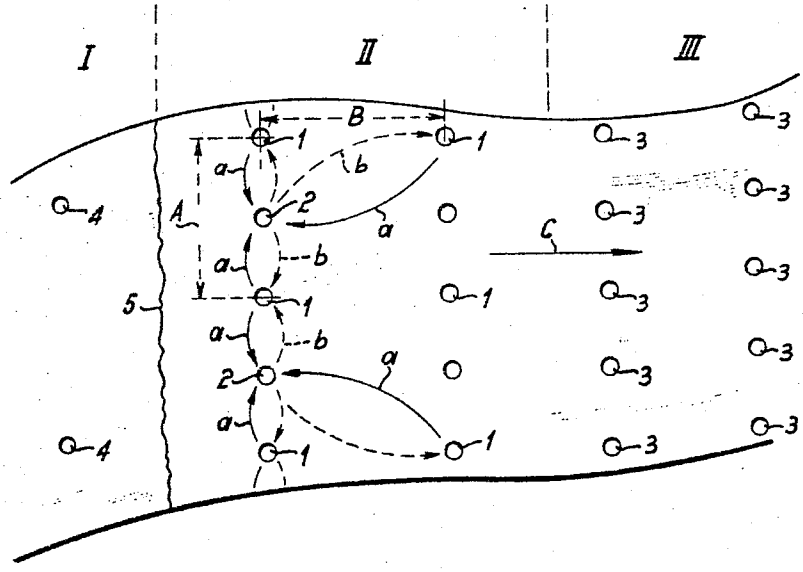
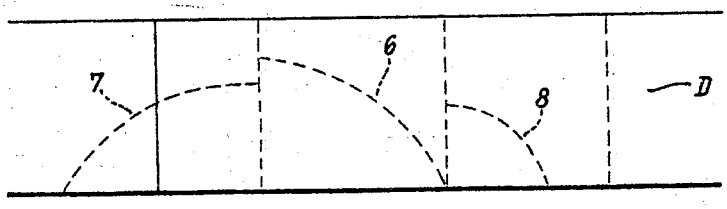


FIG. 2



INVENTORS
GUNTHER SCHLICHT, deceased
(Legal representative)
ERIKA MARIE SCHLICHT
HANS LANGE
By Toulmin & Toulmin
Attorneys

Oct. 4, 1966 G. SCHLICHT ETAL 3,276,518
PROCESS FOR EXTRACTING LIQUID BITUMENS FROM AN UNDERGROUND DEPOSIT
Filed Aug. 6, 1962 2 Sheets-Sheet 2

FIG. 3

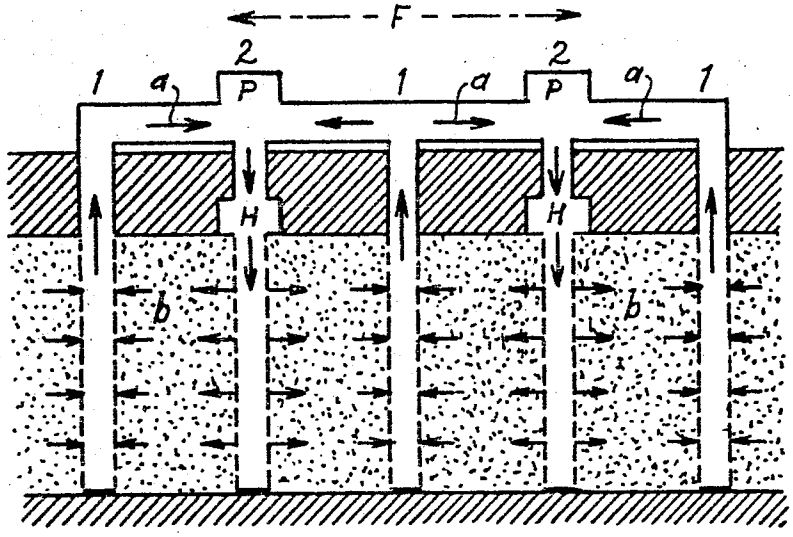
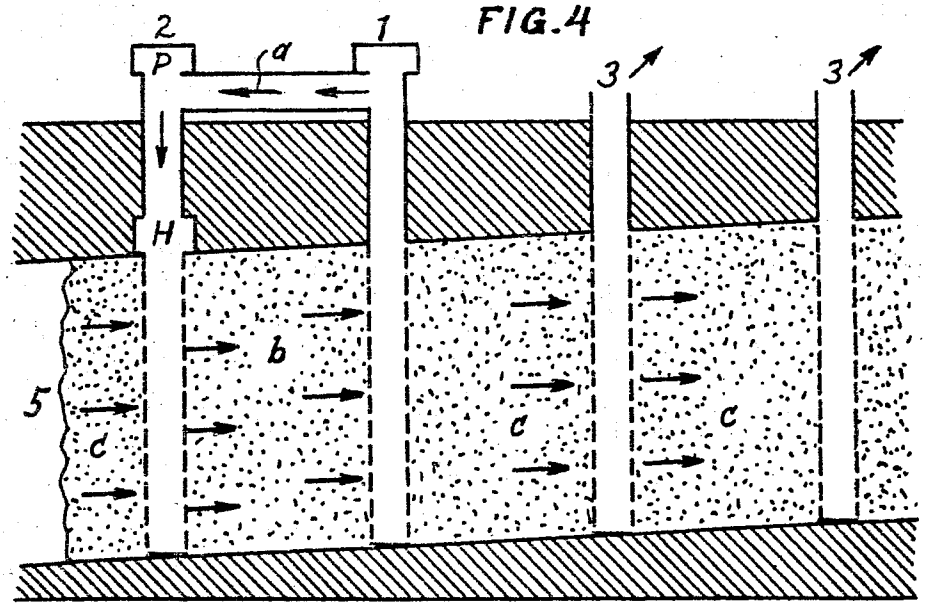


FIG. 4



INVENTORS
GÜNTHER SCHLICHT, deceased,
by Erika Marie Schlicht,
legal representative
HANS LANGE
BY Krafft & Wellé
ATTORNEYS

United States Patent Office

3,276,518

Patented Oct. 4, 1966

3,276,518

PROCESS FOR EXTRACTING LIQUID BITUMENS FROM AN UNDERGROUND DEPOSIT

Günther Schlicht, deceased, late of Hamburg-Othmarschen, Germany, by Erika Marie Schlicht, legal representative, Hamburg-Othmarschen, Germany, and Hans Lange, Wietze, Kreis Celle, Germany, assignors to Deutsche Erdöl-Aktiengesellschaft, Hamburg, Germany

Filed Aug. 6, 1962, Ser. No. 215,493

Claims priority, application Germany, Aug. 8, 1961, Sch 30,108

8 Claims. (Cl. 166—11)

The present invention relates to the extraction of liquid bitumens, more particularly, to a primary extraction process for extracting liquid bitumens from underground deposits wherein the pressure of the deposit is greater than the bubble pressure of the liquid bitumen.

In order to extract liquid bitumens from underground deposits many processes have been devised to treat the deposit to facilitate the extraction of the bitumen. Some processes are based on decreasing the viscosity of the bitumen by heating the deposit through the use of various heating media. Many of these processes are carried out by using one bore through which a medium is introduced and an adjacent bore from which the bitumen is extracted. The heating medium, such as a gas or water, is added to the underground deposit in such a way that the underground circulation of this medium in the deposit from the introduction bore to the extraction bore is at an angle of about 0 degrees with respect to the direction in which the deposit is being exploited.

Many of these secondary extraction processes include the introduction of water through one bore and flowing the water underground through the deposit to an adjacent bore from which the water and the bitumens are extracted. Other processes wherein a heating medium is used which does not originate from the deposit and which may comprise hot water or steam is introduced into the deposit through one bore, flowed underground through the deposit and withdrawn through an extraction bore together with the bitumens.

Other processes include the positioning of electrical heating arrangements in boreholes, so as to heat the adjacent deposits and render them viscous, whereby the deposits can then be flowed to an extraction bore. Since the heat is transferred from the bore to the deposit only by conduction, the efficiency and capacity of such a heating arrangement is limited and is insufficient to produce the necessary quantities of heat for heating large portions of the deposit.

Other methods propose the addition of gases, such as CO_2, or chemicals to the deposit or adding these chemicals to the water used for flooding the deposit.

In the aforementioned processes difficulties are encountered when little or no consideration is given to the action of the introduced medium, such as a gas or liquid, with respect to the underground deposit of the bitumen. One source of difficulty is the failure to pay careful attention to the difference in viscosity between the water and the bitumens in the deposit. Further difficulties arise when these media are introduced through bores which are positioned from the extraction bores along the direction in which the deposit is to be extracted. When the junction surface between a liquid bitumen, such as oil, and the water used for flushing bitumen is moving toward the extraction boreholes and care is not taken to maintain a uniformity in this junction surface, there is the ever-present risk that channels are formed from the action of this water in the underground deposit, particularly when the permeability of the deposit is changing. It is virtually impossible to uniformly treat the junction zone between the oil and water with any of the known processes, since these processes cannot be readily controlled.

It is therefore the principal object of the present invention to provide a more effective process for the extraction of liquid bitumens from underground deposits.

In order to carry out the present process a series of boreholes are drilled into an underground deposit of liquid bitumens and extending in the direction of the deposit. The boreholes are drilled to the lowest point of the deposit in a direction proceeding to the highest point of the deposit which is the direction in which the bitumens are to be extracted. Water is introduced into the deposit through the boreholes in the deepest part of the deposit and the bitumens are extracted from the deposit from boreholes in a higher part of the deposit. Boreholes positioned between the flooding and extracting boreholes are used for treating the liquid bitumens. The contents of the deposit are circulated between one of these latter bores in a closed pipe system wherein the bitumen is brought aboveground, heated, perhaps treated with a chemical substance and introduced into a return borehole to the underground deposit. It is also possible to heat the bitumen in the return borehole. The contents of the deposit then circuate underground from one borehole to the other in a direction which forms an angle of from 45 to 90° in the direction in which the deposit is to be exploited.

Substances which are known per se are added to the bitumens to reduce the surface tensions between the junction surfaces of the oil and water, as this junction surface approaches the treating bores.

The liquid bitumens are generally circulated several times between the treating boreholes, in order to transfer sufficient heat to the surrounding rock formation in order to heat the same.

During this process water is added to the flooding boreholes to maintain a sufficient pressure on the underground liquid bitumens, so that this pressure remains above the bubble pressure of the liquid bitumen. In the event the pressure is decreased below the bubble pressure, gaseous bubbles will form in the individual pores of the rock storing the liquid bitumen and will accordingly make the deposit compressible. As a result, it will become increasingly difficult to transfer heat from the borehole into the deposit and thus large portions of heat will be rendered ineffective. The bubble pressure of the liquid bitumen is considered that point at which gases in the bitumen begin to escape at that temperature of the underground deposit.

Other objects and advantages of the present invention will be apparent upon reference to the accompanying drawing which schematically illustrates the manner in which the present process is carried out.

An understanding of the invention may be facilitated by an inspection of the drawings wherein:

FIGURE 1 schematically illustrates a top plan view of a portion of an underground deposit of liquid bitumens;

FIGURE 2 schematically illustrates a vertical cross section of FIGURE 1, showing the variations in temperature as different sections of the deposit are being treated;

FIGURE 3 illustrates a vertical cross section of a portion of an underground deposit of liquid bitumens showing the flow paths between the leading bores 1 and the treating bores 2 with the flooding zone F, pumps P and heaters H; and

FIGURE 4 illustrates a vertical cross section of a portion of an underground deposit of liquid bitumens showing the flow path from the junction of the oil and water indicated at 5, past the leading and treating bores 1 and 2, to the extraction boreholes 3.

Into the deposit of liquid bitumens a number of boreholes are drilled in a pattern substantially as that illus-

trated in the drawings, with particular reference to FIGURES 1 and 4. This portion of the underground deposit can be divided into 3 sections indicated by I, II and III. Section I is the water or flooding section and represents the deepest or lowest part of the underground deposit. The boreholes 4 extend downwardly into this water section.

The extraction section III is positioned in the highest portion of the deposit and has a plurality of boreholes 3 extending downwardly thereinto.

The treating section II is positioned between the water section I and the extracting section III and has a plurality of boreholes therein whose specific functions will be presently described.

As the extraction of the deposit proceeds the boreholes of section I will be moved in the direction of the extraction which is represented by the arrow *c*.

During the extraction process water is introduced into the boreholes 4 in section I to maintain a pressure on the liquid bitumens of the underground deposit. The liquid bitumens, such as oil, are then withdrawn from the boreholes 1 which are designated as withdrawing or leading boreholes. As the oil is withdrawn from the boreholes 1 it is utilized as a heating medium for further heating the underground deposit and also as a medium for carrying added substances to the underground deposit to facilitate the extraction of the oil.

As particularly shown in FIGURES 3 and 1, one or more leading boreholes 1 are coordinated to an adjacent treating bore 2. In the treating bore 2 the oil withdrawn through borehole 1 is heated by a source of heat positioned either underground or aboveground for lowering the viscosity of the oil. The oil is then returned to the deposit downwardly through treating borehole 2.

The flow of the oil aboveground from leading borehole 1 to treating borehole 2 is effected through a closed heat-sealed pipeline which is provided with a suitable pumping arrangement for increasing the pressure of the oil. The circulation of the oil aboveground between boreholes 1 and 2 is in the direction of solid arrow *a* and underground the oil flows from treating borehole 2 to leading borehole 1 in the direction of the dashed arrow *b*. The leading bores 1 are so positioned with respect to the adjacent treating bores 2 that these directions of flow form an angle of from 45 to 90° with respect to the general direction of extraction as indicated by the arrow *c*. This produces a uniformly high zone of heat between the leading and treating bores which zone moves in the direction of *c* until it reaches the next series of boreholes, where the zone is again formed, if necessary, to continue the extracting process.

As the contents of the deposit, i.e. the oil, is circulated between boreholes 1 and 2 the oil is extracted from the extracting borehole 3 and simultaneously with this extraction flood water is added through the flooding bores 4 in order to maintain the pressure on the oil within the deposit. A pressure on the oil is maintained which is greater than the bubbling pressure of the oil.

The heated oil is circulated through the boreholes 1 and 2. As the junction of the oil and water, as indicated at 5, proceeds in the direction of the arrow *c* and approaches the leading boreholes 1, substances are then added to the circulating oil for improving this oil-water junction. These substances are added to decrease the interfacial and surface tensions between the contacting surfaces of the oil and the water. The approach of the oil-water junction 5 is indicated by samplings taken from the leading bores 1. The first traces of water in the oil as revealed in the samplings taken from the leading boreholes 1 will indicate the approaching of the oil-water junction 5. By the adding of these substances which will vary in quantity and composition according to the analysis of the sample the oil will be more readily extracted from the rock formations adjacent the oil-water boundary 5 and is more easily freed from the water.

These samples taken from the leading boreholes will give accurate indications since the oil must be circulated through the leading and treating boreholes several times in order to sufficiently heat the underground rock formations bearing the oil. These rock formations have a porosity of about 25% and it is therefore necessary to circulate a quantity of heated oil which is from 2–6 times the quantity of the liquid contained in the rock formations. Circulating of this quantity of heated oil will transfer sufficient heat to the rock formations to release the oil therefrom. Thus it is apparent that the circulating oil will pass several times by the point from which the sample is taken.

After the oil-water junction 5 has passed the leading bores 1 and the samples indicate that nothing but water had seen discharged from the leading boreholes, the leading bores are then employed as the flooding boreholes. When the leading boreholes are now used as the flooding boreholes the entire extraction process is moved to the next boreholes in the direction of arrow *c* and repeated. Also after the oil-water junction 5 has passed the leading boreholes 1 as shown in the drawing, the substances may then be added to the flooding water in order to improve the interfacial and surface tensions between the contacting oil and water surfaces.

The most essential factor for the satisfactory extraction of oil from the deposit according to the present invention is the ratio of the viscosity of the oil to that of the water. If the viscosity of the water is close to that of the oil or even greater than the viscosity of the oil, the removal of the oil from the deposit can be more easily and rapidly achieved. The viscosity of the aqueous phase can be increased in the usual way by adding suitable and known chemicals. By way of example, carboxymethylcellulose or cement may be added to the salt water. However, more satisfactory results are obtained by the addition of substances which increase the viscosity of the water and simultaneously decrease the specific gravity thereof as, for example, emulsions of oil in water (5 to 20% of oil in water) which emulsions can readily be prepared from the flooding water and the crude oil contained in the deposit.

The yield of oil from the deposit can be further increased by adding CO_2 in a known manner to the circulating medium consisting of oil and water. Concentrations of CO_2 from 15–30% are preferable. The carbon dioxide is added to the circulating oil just before the oil-water junction zone approaches the leading and treating boreholes. Under these conditions only small quantities of oil must be enriched with CO_2. The oil then carries the CO_2 to the water in the deposit from which it is further transmitted to the flooding water. Thus, when the oil is enriched with CO_2 the CO_2 is then automatically transmitted to the moving flooding water.

By the application of these substances as described above, the relationship between the viscosities of the oil and water is improved to increase the speed by which the extraction of the oil is carried out. The presence of these substances in the oil and water will preclude the formation of channels in the deposits between the oil and water. However, when the speed of flow of the oil through the deposit is increased the friction is also correspondingly increased and accordingly losses in pressure will arise. In order to compensate for these pressure losses the flooding water is increasingly flooded through the bores which are positioned in the flooding water section just after the oil-water junction has passed.

The entire deposit is divided into treating sections which may be treated separately according to the present invention. The length of such a treating section is indicated by B and is defined by the distance between successive leading bores. The width of the treating section is indicated at A and is defined by twice the space between two leading bores of a series. The series of bores positioned in the direction of arrow *c* of section II can be treated only

successively. This is of an advantage, since the experience gained by treating a previous section can be taken into account when treating subsequent sections. The adjoining treating sections in section II can be treated simultaneously.

FIGURE 2 of the drawing schematically illustrates a vertical cross-section through the deposit and shows the variations of temperature as different sections of the deposit are treated. The variation of the temperature in the present treating section, i.e. that defined by A and B is shown at 6, and 7 indicates the gradually increasing temperature in the treating section which has become incorporated into the flooded section I. Curve 8 shows the heat in the next successive treating section which heat is introduced primarily by the heat exchange between the heated flooding water and the circulating oil.

Thus it can be seen that the process according to the present invention provides for thoroughly and continuously extracting the contents of an underground deposit of liquid bitumens step by step wherein the process can be closely controlled according to conditions encountered in the deposit. The important conditions are encountered primarily in the area of the oil-water junction surface. The deposit is partially heated by one treating section after the other with the contents of the deposit serving as the heating medium. The heating of the deposit decreases the viscosity of the oil and establishes a better relationship between the viscosities of the oil and water, so as to enable a more rapid and complete extraction of the oil from the deposit. The heated contents of the deposit are circulated between neighboring boreholes of the treatment section II. While the heated contents are circulated under pressure in a closed pipe system aboveground, a substance is introduced into the heated contents to either change the physical properties or adapt them to given conditions as indicated by periodic samples taken from the circulating oil. In addition to the rapid and complete extraction of the liquid bitumens from the deposit, losses are reduced by avoiding the formation of water channels in the deposit.

The efficiency of the process can be further improved by preventing excessive losses of heat from the circulating oil. This can be accomplished by insulating the pipelines positioned in the treating and leading boreholes with a plastic foam surrounded by plastic tubes. In addition CO_2 may be introduced under pressure between these pipelines and the walls of the respective bores so as to expel the air accumulating therein. Thus the insulation against heat losses is improved by about 40%. In addition, this CO_2 may be maintained at a pressure less than atmospheric so that humidity therein is evaporated.

In order to avoid excessive cross-currents between the insulation and the walls of the boreholes the pipelines within the boreholes are provided with spacers which center the pipelines within the boreholes and subdivide the length of the borehole into smaller sections.

To further assist in the comprehension of the present invention, a specific operating example of this process will next be described in detail.

A paraffinic petroleum deposit sealed under a pressure of 113 atmospheres was exploited. The rocks of the deposit consisted of an oil sand having a porosity of 25% and an average permeability of 600 millidarcys. The deposit was located in an anticline in an ascending depth ranging from 100 to 3,100 m. and was about 30 m. thick, Its extension in length was 4,000 m. and its average width 1,500 m.

The deposit was developed by rows of bores, whereby the individual bores were arranged at a distance of 250 m. from each other over the width of the deposit and at a distance of 250 m. in the longitudinal direction of the field. The bores extended down to several meters beyond the bottom edge of the oil deposit. The diameter of the bores was 216 mm. The bores were lined with strings of casing of a diameter of 168 mm. into which an ascending tube having a diameter of 77.8 mm. was mounted. This tube was provided with an insulation layer having a thickness of 20 mm. and surrounded with a thin-walled plastic casing. The air between the exterior casing and the ascending tube was displaced by CO_2 and then partially evacuated. Aboveground the bore tubes were connected with a closed intermediate container and a pump. The two rows of bores adjacent flooding section I served as so-called treatment section. In adjacent bores of a transverse row each second bore served as a treating bore. All of the other bores served as leading bores. Oil was extracted through the leading bores under a pressure maintained therein and pressed through the neighboring treating bores again into the deposit where it was heated. A nuclear reactor served as a source of heat.

The process was started by introducing under pressure 10 $m.^3/h.$ of flushwater into the first row of the flushing bores and extracting 9 $m.^3/h.$ of oil from the extraction bores. 6 $m.^3/h.$ of oil was simultaneously extracted through the leading bores aboveground and reintroduced by means of the pump at a pressure of 60 atmospheres above the closing pressure through the neighboring treating bores into the deposit and heated to a temperature exceeding that of the deposit by 75° C. With a careful flushing in the beginning and extracting only small quantities of liquid, the oil is mostly circulated between the leading and the treating bores. As the heating of the oil rising through the leading bores proceeded, the circulating quantity of oil was slowly increased simultaneously with the quantity of the flush water and that of the extracted oil.

After a circulation of 120 days a decrease in the viscosity of the circulating oil was observed, conditioned by the temperature. After another 100 days the discharged oil reached the desired temperature. First traces of water indicated that the oil-water junction zone was approaching the first row of bores of the treating section. 20% by volume of CO_2 were then added to the oil prior to its entering the treating bore. When the circulating medium discharged from the leading bores contained more than 50% of water, the mixture of oil and water arriving through the circulation was emulsified in addition to the carbon dioxide.

The discharge of pure water from the leading bores after another 60 days indicated that the oil-water junction zone had passed by the first row of bores of the treating section. Thereafter the circulation through the first rows of bores of the treating section was stopped and said bores then used as flushing bores.

The water emerged after 260–350 days from the new row of bores in the treating section, so that the next row could be incorporated. The exploitation of the field was continued.

The output of the 10 bores of the extraction zone was 450 $m.^3$ per day and one quarter of the field has been exploited after 3 years. The oil yield of the deposit is 30% higher than in case the usual flushing and extraction process without a treating section had been applied.

It will be understood that this invention is susceptible to modification in order to adapt it to different usages and conditions, and, accordingly, it is desired to comprehend such modifications within this invention as may fall within the scope of the appended claims.

What is claimed is:

1. In the process of extracting liquid bitumens from underground deposits the pressure of which exceeds the bubble pressure of the liquid bitumens, the steps of forming a plurality of bores into the underground deposit of liquid bitumens in the direction of exploitation of the deposit, extracting the liquid bitumens from bores into the highest portions of the deposit, flooding water through other bores into the deepest portions of the deposit simultaneously with the extracting of the liquid bitumens to maintain a pressure on the liquid bitumens which is greater than the bubble pressure thereof, withdrawing liquid bitumens derived from the deposit from bores in an inter-

mediate zone between the flooding and extracting bores, and heating the withdrawn bitumens and recirculating the so heated bitumens through other bores located between said flooding and extracting bores into the deposit to heat the same, the direction of movement of the liquid bitumens circulating underground between withdrawing and treating bores forming an angle of 45 to 90° with the direction in which the deposit is being exploited.

2. In the process of extracting liquid bitumens from underground deposits the pressure of which exceeds the bubble pressure of the liquid bitumens, the steps of forming a plurality of bores into the underground deposit of liquid bitumens in the direction of exploitation of the deposit, extracting the liquid bitumens from bores into the highest portions of the deposit, flooding water through other bores into the deepest portions of the deposit simultaneously with the extracting of the liquid bitumens to maintain a pressure on the liquid bitumens which is greater than the bubble pressure thereof, withdrawing liquid bitumens from bores between the flooding extracting bores, and heating the withdrawn bitumens and recirculating the so heated bitumens through other bores located between said flooding and extracting bores into the deposit to heat the same, and adding substances to the water to improve the extraction qualities of the liquid bitumens as the junction between the water and the liquid bitumens passes the withdrawing bores.

3. In the process of extracting liquid bitumens from underground deposits the pressure of which exceeds the bubble pressure of the liquid bitumens, the steps of forming a plurality of bores into the underground deposit of liquid bitumens in the direction of exploitation of the deposit, extracting the liquid bitumens from extracting bores into the highest portions of the deposit, flooding water through flooding bores into the deepest portions of the deposit simultaneously with the extracting of the liquid bitumens to maintain a pressure on the liquid bitumens which is greater than the bubble pressure thereof, withdrawing liquid bitumens from leading bores between said flooding and extracting bores, and heating the withdrawn bitumens and recirculating the so heated bitumens through treating bores located between said flooding and extracting bores into the deposit to heat the same, said leading and treating bores having walls and pipelines passing therethrough defining spaces therebetween, and introducing CO_2 into said spaces to insulate against heat losses from the heated liquid bitumens.

4. In the process as claimed in claim 3 wherein the CO_2 is maintained at a pressure less than atmospheric.

5. In the process of extracting liquid bitumens from underground deposits wherein the pressure exceeds the bubble pressure of the gases dissolved in the liquid bitumens, the steps of forming a plurality of bores into an underground deposit of liquid bitumens in the direction of the highest portion of the deposit, extracting said liquid bitumens from extracting bores positioned in a section of the highest portion of said deposit, flooding water through flooding bores positioned in a section of the deepest portion of said deposit and simultaneously with said extracting of the liquid bitumens maintaining a pressure on said liquid bitumens higher than the bubble pressure of the gases dissolved in the liquid bitumens, circulating the contents of said deposit without production therefrom in a circulating section of said deposit defined by leading bores and treating bores located between said flooding bores and said extraction bores said circulating the contents comprising withdrawing a portion of said contents through said leading bores, heating said portion of said contents and recirculating said portion of said contents through said treating bores whereby said contents are heated, the viscosity of said liquid bitumens is lowered and said liquid bitumens are advanced in the direction of said extraction bores.

6. The process as defined in claim 5, wherein said contents are brought to the surface through said leading bores and said contents are again returned to said deposit through said treating bores without separation of any of the components of said contents with closed circulating between said treating bores and said leading bores whereby heat is distributed throughout said deposit.

7. In the process of extracting liquid bitumens from underground deposits wherein the pressure exceeds the bubble pressure of the gases dissolved in the liquid bitumens, the steps of forming a plurality of bores into an underground deposit of liquid bitumens in the direction of the highest portion of the deposit, extracting said liquid bitumens from extraction bores positioned in a section of the highest portion of said deposit, flooding water through flooding bores positioned in a section of the deepest portion of said deposit whereby an oil-water contact surface results between said water and said liquid bitumens and simultaneously with said extracting of the liquid bitumens maintaining a pressure on said liquid bitumens higher than the bubble pressure of the gases dissolved in the liquid bitumens, circulating the contents of said deposit without production therefrom in a circulating section of said deposit defined by leading bores and treating bores located between said flooding bores and said extraction bores said circulating the contents comprising withdrawing a portion of said contents through said leading bores, heating said portion of said contents, adding substances to said liquid bitumens to improve said oil-water contact surface as said oil-water contact surface approaches said leading bores, adding substances to said water to improve said oil-water contact surface as said oil-water contact surface passes said leading bores and recirculating said portion of said contents through said treating bores whereby said contents are heated, the viscosity of said liquid bitumens is lowered and said liquid bitumens are advanced in the direction of said extraction bores.

8. In the process of extracting liquid bitumens from underground deposits the pressure of which exceeds the bubble pressure of the liquid bitumens, the steps of forming a plurality of bores into the underground deposit of liquid bitumens, extracting the liquid bitumens from bores into the highest portions of the deposit, flooding water through other bores into the deepest portions of the deposit simultaneously with the extracting of the liquid bitumens to maintain a pressure on the liquid bitumens which is greater than the bubble pressure thereof, withdrawing liquid bitumens derived from the deposit from bores in an intermediate zone between the flooding and extracting bores, heating the withdrawn bitumens and recirculating the so heated bitumens through other bores located between said flooding and extracting bores into the deposit to heat the same, said recirculating continued to heat the deposit in the intermediate zone to release substantially all the liquid bitumens from said deposit whereby substantially all of said liquid bitumens is recoverable.

References Cited by the Examiner

UNITED STATES PATENTS

2,800,962	7/1957	Garst	166—9
2,827,964	3/1958	Sandiford et al.	166—9
2,841,375	7/1958	Salomonsson	166—11 X
2,862,558	12/1958	Dixon	166—40
2,875,831	3/1959	Martin et al.	166—9
3,057,403	10/1962	Wyllie	166—11 X
3,080,918	3/1963	Natland	166—39 X

FOREIGN PATENTS

726,712	3/1955	Great Britain.

CHARLES E. O'CONNELL, *Primary Examiner.*

BENJAMIN HERSH, *Examiner.*

S. J. NOVOSAD, *Assistant Examiner.*