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OIL RECOVERY PROCESS

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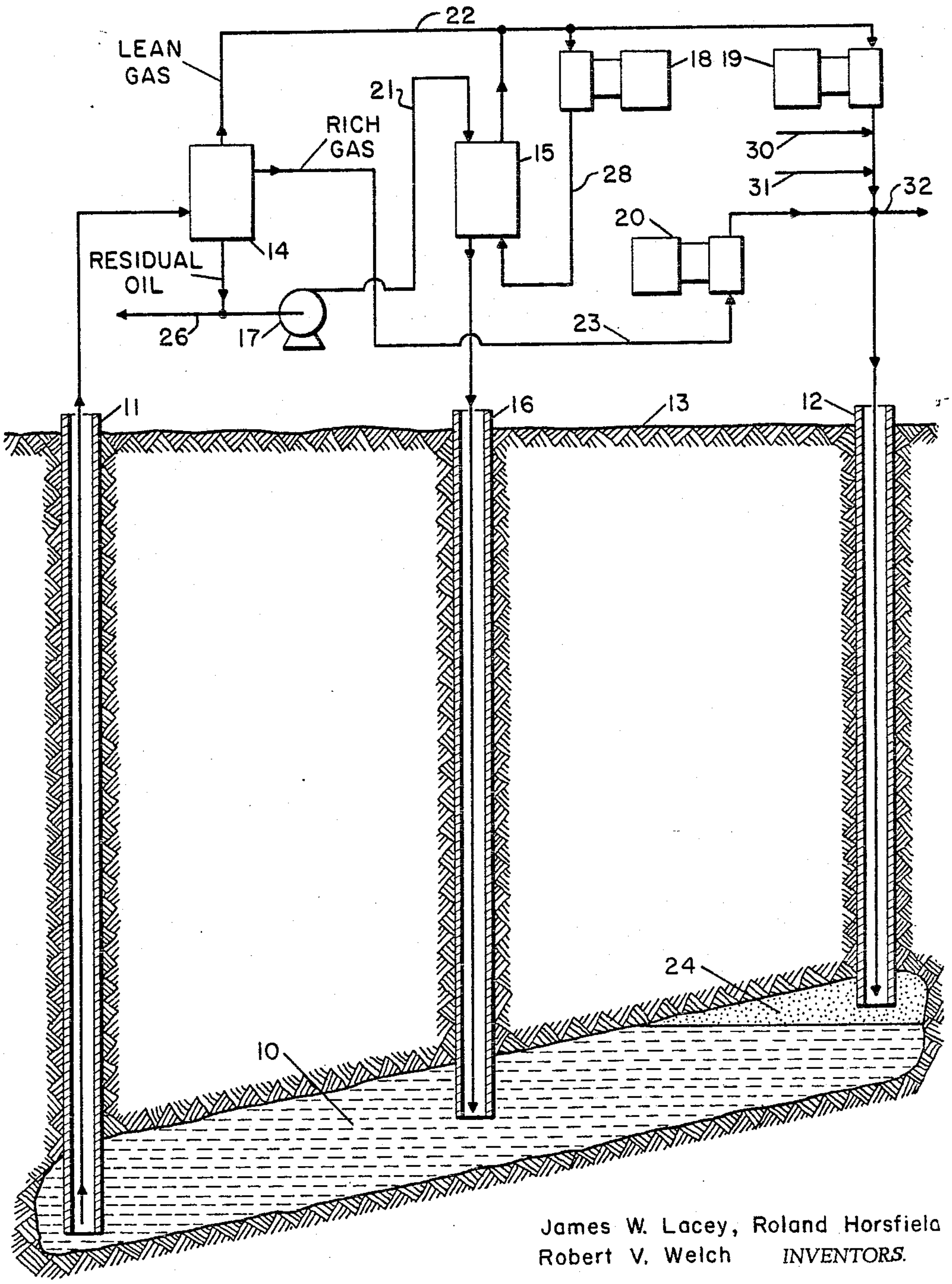

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OIL RECOVERY PROCESS

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This invention concerns an improved method of recovering oil from underground reservoirs. The invention, more especially, concerns an improved miscible displacement-type oil recovery process wherein a bank or slug of material miscible with the oil in a reservoir is used to displace oil from the reservoir. The invention particularly relates to a slug-type miscible displacement process for recovering oil from an underground reservoir wherein the miscible slug comprises material obtained directly from the reservoir itself.

In recent years, the oil industry has been working with new and improved methods for recovering petroleum from underground reservoirs. A particularly attractive class of such methods consists of the so-called miscible displacement processes wherein a fluid, which is miscible with the oil in a given reservoir under the reservoir conditions of temperature and pressure, is injected into the reservoir so as to displace oil from the reservoir. The displacing fluid is preferably miscible with the oil under such conditions to the extent necessary to form a single fluid phase with the oil.

For various reasons, including those of economics, it has been the general practice in conducting a miscible displacement process to limit the amount of the oil-displacing agent used to a relatively small bank or slug. A bank or slug is formed in the reservoir about one or more input wells and is then driven through the reservoir toward one or more output wells by means of a suitable drive agent. Normally speaking, the bank or slug comprises between about one and thirty-five percent, and preferably between five and fifteen percent, of the hydrocarbon pore volume of the portion of the reservoir subjected to the process. The size of the bank used in any given case may vary considerably, depending on the cost and availability of the materials used in the bank, the structure of the reservoir, the degree of increased recovery desired, etc.

The drive fluid or agent used to drive the bank or slug is, itself, normally substantially immiscible with the reservoir oil. However, the operating conditions for the overall process, and the compositions of the drive fluid and the miscible slug, are preferably chosen such that the slug and the drive fluid form a single fluid phase. Thus, the slug is not only completely miscible with the reservoir oil but also with the driving fluid under the conditions of temperature, pressure, etc., prevailing within the reservoir. In other words, no phase interface is discernible between the reservoir oil and the miscible slug, nor between the slug and the fluid used to drive the slug.

Materials that appear especially attractive for use in the miscible slug of a slug-type miscible displacement process include ethane, propane, and the butanes, pentanes, and mixtures of volatile hydrocarbons such as LPG. LPG (liquefied petroleum gas) is simply a hydrocarbon mixture consisting principally of propane and butane in liquified form. LPG may also contain minor portions of ethane, pentanes, hexanes, and even heptanes.

As noted above, the miscible slug in a miscible slug process is preferably completely miscible with the fluid which is used to propel the slug. Thus, a slug comprising volatile hydrocarbons (e.g., C_2–C_4 hydrocarbons) is preferably driven by a gas (e.g., methane, natural gas, lean natural gas, or the like) which at the reservoir conditions of temperature and pressure form a single fluid phase with one another. Typically, in the case of a miscible slug consisting of propane and a drive gas consisting of methane, a reservoir must be operated at a pressure of at least about 1325 p.s.i. when the reservoir temperature is about 100° F., if a single fluid phase of the propane and the methane is to be achieved.

A number of specific forms of miscible displacement processes have been reported in the literature—see, for example, United States Patents 2,724,437; 2,724,438; and 2,880,801. These publications, in addition to describing specific forms of processes, also describe experimental procedures for determining how to insure completely miscible systems. Other publications of interest include "Miscible Fluid Displacement—Prediction of Miscibility"; A. L. Benham et al.; Petroleum Transactions, AIME (1960), volume 219, page 229; and British Patent No. 696,524.

One of the great deterrents to the application of miscible displacement processes has been the fact that such processes need large amounts of the materials required to establish miscibility with oil. This is true even when using small banks of such materials in small reservoirs. Since the materials must, in general, be injected during a relatively narrow interval of time, it has been necessary to transport large quantities of the materials by tank car, truck or the like to a reservoir site. The expense entailed in the purchase and transportation of the materials has naturally detracted very seriously from the economics of miscible displacement processes. It has also been necessary, in some instances, to use smaller banks or slugs of oil-miscible materials than it would otherwise have been desirable to use. Again, it has been generally necessary to limit the application of the miscible displacement processes to small portions of a reservoir, thereby making for serious inefficiencies.

It is, accordingly, a major object of the present invention to provide a more satisfactory means for making miscible slug materials more readily available and at reduced cost for use in miscible displacement processes. It is a more particular object of the invention to avoid the need for transporting large quantities of such materials to a reservoir from distant points of supply. It is a further object of the invention to supply large quantities of miscible slug materials at the very time when such materials are needed in a miscible slug process, and to thereby permit the use of larger slug sizes and the treatment of larger portions of reservoirs.

The present invention makes attainment of the above objects possible by providing means for obtaining the materials needed to form the miscible slug of a slug-type miscible displacement process directly from the reservoir to be produced by the process. At the same time, fluids are injected into the reservoir in sufficient quantity to maintain the reservoir pressure at a level sufficient to assure the desired miscible relationship within the reservoir.

More specifically, the invention achieves the above objectives by first producing oil from a reservoir in quantities greater than actually desired for sale or use away from the reservoir. More particularly, the rate of production is selected, as will become more apparent later in this description, to maintain the desired rate of injection into the reservoir of the materials needed to form a miscible slug. The oil thereby produced is flashed, fractionated, or otherwise treated so as to recover at least three streams or fractions from the oil. The first stream is essentially a lean natural gas comprising in the main methane with minor quantities of ethane, propane, nitrogen, and the like. Substantially very little, if any, hydrocarbons such as butanes or pentanes will normally be present in this stream.

The second stream comprises an enriched gas consisting primarily of intermediate volatile hydrocarons such as ethane, propane, and butanes. Quantities of other materials such as pentanes, hexanes, heptanes, carbon dioxide, and the like may also be present. These latter materials, however, will normally occur in only very minor quantities.

The third stream comprises simply the produced oil itself devoid of the materials removed in the first and second streams, above.

The separation of the three streams is carried out such that the second stream comprises a material which is miscible in all proportions with the reservoir oil under the conditions of temperature and pressure existing within the reservoir. This stream is reinjected into the reservoir, at least in part, at one or more points spaced from the points at which oil is being produced from the reservoir.

At least a part of the residual or stripped oil stream—i.e., the third stream—is also reinjected into the reservoir during this period of operation. This stream, however, is injected at one or more points within the reservoir which are remote from the points of oil production and also the points of reinjection of the second stream. It is specifically intended that the residual oil be reinjected so as not to be re-produced from the reservoir during the initial phase of production when the purpose of such production is to obtain the materials needed to form a miscible slug for use in the reservoir. Nor should the reinjected oil come in contact within the reservoir with the reinjected second stream during this phase of the operation. A portion of the residual oil may, of course, be sold or otherwise consumed as desired.

Prior to reinjection of the residual oil into the reservoir, this oil is preferably contacted with the lean natural gas fraction so as to substantially saturate the oil with the gas. Any remaining portion of the lean gas may be reinjected into the reservoir, alone or in conjunction with the residual oil. Like the reinjected residual oil fraction, the lean gas fraction should be reinjected at a point remote from the point or points of oil production as well as the point or points where the enriched gas fraction is reinjected.

Reinjection of the lean gas, the residual oil, and the enriched gas fractions should be continued until a bank of the enriched gas is formed within the reservoir about the input wells that are used to inject this material. The magnitude of each bank thus formed should preferably be sufficient such that it will promote the recovery of oil from the reservoir upon traveling through the reservoir toward one or more output wells. It is particularly contemplated that each such bank be sufficiently large to move entirely through the reservoir from its respective input well to its respective output well or wells.

Once the size of each miscible slug or bank has reached the desired size, the recycling or reinjection of the residual oil fraction and the enriched gas fraction is stopped. At this point, the residual oil fraction may be sold or otherwise transported from the reservoir as is usually the practice in producing operations. The enriched gas stream may also be similarly disposed of. At least a portion of the lean gas fraction, however, should be reinjected into the reservoir behind each miscible slug or bank so as to propel the slug or bank through the reservoir. It is essential, as noted earlier, that the reinjected lean gas form a single fluid phase with the miscible slug. To this end, the reservoir pressure must be maintained at a level sufficient to maintain the slug in a completely miscible relationship with both the reservoir oil and the lean gas. It will be apparent, of course, that some of the enriched gas fraction may be blended with the inert gas fraction so as to promote miscibility in the reservoir between the slug and the latter fraction. Alternatively, the separation between the lean gas fraction and the enriched gas fraction may be altered so as to modify the composition of the lean gas fraction.

Throughout the operation of the present invention, it is essential that the volumes of fluids injected into a reservoir be sufficient, when viewed in light of the volumes of fluids produced from the reservoir, as to maintain the desired level of pressure within the reservoir. If, for any reason, the volume of reinjected fluids is insufficient at any time for this purpose, extraneous fluids may be also injected. For example, lean gas from an adjacent reservoir may be injected into the reservoir. Alternatively, water may be injected into the reservoir at a point sufficiently remote from the various input and output wells so as not to interfere with the desired mechanisms and miscible relationships referred to above. With respect to water injection, it is particularly contemplated that water may be injected simultaneously with, or in sequence with, the lean gas used to drive a miscible slug through the reservoir. The combined use of water and gas in this fashion has been indicated by workers in the art to improve the conformance of miscible displacement processes. In other words, the combination of lean gas and water enables the miscible displacement process to sweep larger portions of a reservoir than would be possible with the lean gas alone.

While the present invention has general application to petroleum reservoirs, it is especially suited for reservoirs having characteristics allowing a high degree of gravity drainage. Thus, it is well known in the art that a fluid of low viscosity tends to travel faster through a porous medium than does a fluid of greater viscosity, other factors being equal. Therefore, in the case of a miscible displacement process where a slug of relatively low-viscosity material is used to drive a relatively viscous reservoir oil, the slug tends to finger ahead into the oil and lose its slug configuration. As a result, the beneficial effect of the slug material is seriously diminished and may be lost altogether.

The tendency of a miscible slug to finger is particularly the case in substantially horizontal reservoirs. In tilted reservoirs or reservoirs having substantial vertical permeabilities, on the other hand, the tendency is substantially eliminated, since the miscible slug in addition to being less viscous than the reservoir oil is also lighter. In other words, if a miscible slug is injected into the upper portion of such a reservoir and driven down through the reservoir, the fingering tendency of the slug is overcome or greatly reduced in view of the gravity effect tending to "float" the slug above the reservoir oil. The interplay of these two effects and their magnitude have been discussed in a publication entitled "Miscible Fluid Displacement in Porous Media," Lacey et al., Journal of Petroleum Technology, April 1958, page 76.

This invention may be better understood by reference to the drawing which forms part of this application and illustrates the best mode contemplated for practicing the invention. The drawing depicts a tilted reservoir **10** penetrated by output well **11** and input wells **12** and **16** which extend to the surface of the earth **13**. Also depicted is a gas/oil separator **14** which may conveniently consist of a series of staged separators designed to release volatile constituents (e.g., "casing head gas") from the produced reservoir oil at progressively lower pressures. Also shown is an oil/gas contacting zone **15** and pumps or compressors, as the case may be, **17**, **18**, **19**, and **20**.

In applying the process of the present invention to reservoir **10**, operation is started by producing reservoir oil through output well **11** to the surface of the earth. Here, the produced oil is separated in separation zone **14** to form a lean gas fraction, a rich gas fraction, and a residual or stripped oil fraction. The residual oil flows through line **21** to gas/oil contacting zone **15**, where it is saturated with at least a portion of the lean gas fraction at an elevated pressure—preferably about reservoir pressure. The lean gas reaches zone **15** by flowing through line **22** and compressor **18** and line **23**. The saturated residual oil from zone **15** is returned to reservoir 10 through input well 16. Input well 16 is located such that the reinjected residual oil is not again produced from the reservoir until late in the recovery process. In this way, it does not interfere with the formation of the miscible slug.

The rich gas fraction flows through line 23, compressor 20, and input well 12 to reservoir 10. In those instances where this fraction is in the liquid phase, compressor 20 will, of course, ordinarily be a pump.

Upon entering reservoir 10 through well 12, the rich gas fraction collects in the vicinity of the input well to form a bank or slug 24 which forms a single fluid phase with the reservoir oil. As explained earlier, it is necessary for the composition of the rich gas to be controlled to achieve this condition. This requires, in turn, that the separation between the lean gas and the rich gas also be controlled. It is preferred, of course, that the rich gas contain as much methane (or other normally lean gas constituents) as possible while still maintaining a completely miscible relationship between the slug 24 and the reservoir oil. Generally speaking, the rich gas fraction will comprise mainly hydrocarbons containing from two to four carbon atoms. Minor amounts of methane, pentanes, and hexanes may also be present. Carbon dioxide may also be present in this fraction, since this material frequently occurs in reservoir oils.

During this phase of the process, a portion of the residual oil from zone 14 may be sold, transported, or otherwise disposed of through line 26. Indeed, it is a characteristic of the invention that normal quantities of oil may be produced and marketed from a reservoir during the formation of the miscible slug 24. Generally speaking, it is contemplated that considerably more residual oil will be recycled to a reservoir in practicing this invention than is sold or transported away—so long as a miscible slug is in the process of being formed. The recycle rate should preferably be sufficient to be compatible with the rate at which rich gas is reinjected. It will ordinarily not be unusual to reinject five or more times as much residual oil as is marketed.

Injection of the rich gas fraction into the reservoir through input well 12 is continued until the bank 24 reaches a preselected size. The size, of course, may vary considerably from reservoir to reservoir, depending upon economic conditions, the relative magnitudes of the fingering and gravity effects of the slug relative to the reservoir oil, the distance between the input well 12 and the output well, etc. The output well toward which the slug is driven may be well 11, but it may also be some other well or wells. For example, as the solvent slug 24 moves through the reservoir from well 12 toward well 11, one or more intermediate wells may be used sequentially as output wells for the reservoir oil.

The size of miscible slug 24 will normally be from about one to thirty-five percent of the hydrocarbon volume of the portion of the reservoir 10 to be swept by the bank. It is particularly contemplated, however, that bank sizes between about five and ten percent of the hydrocarbon volume be employed. It is also preferred that the process be carried out in reservoirs where the fingering tendency of the bank through the reservoir oil is minimal—viz., in tilted reservoirs or reservoirs having substantial vertical permeability.

When the bank 24 has reached the desired size, the injection of residual oil through input well 16 and the injection of rich gas through input well 12 are stopped. The production of reservoir oil through output well 11 is reduced, as may be necessary, to provide only the amount of oil required for transmission through line 26. The rich gas is now sold or otherwise disposed of through line 32; or it simply may be reinjected in some other portion of the reservoir.

The lean gas is now injected through well 12 into the reservoir behind slug 24 so as to propel the slug through the reservoir and away from well 12. Referring specifically to the drawing, for example, slug 24 is shown to be driven by the lean gas toward output well 11. In any event, the lean gas is injected into the reservoir 10 at a pressure sufficient to maintain it in a single fluid phase with the miscible slug 24. The composition of the lean gas may be altered, as desired, to help insure this condition. For example, some of the material previously contained in the rich gas fraction may now be introduced into the lean gas fraction by altering the nature of the separation carried out in zone 14. It is normally preferred, however, that none of the major components of the rich gas be incorporated within the lean gas. If additional fluids beyond the lean gas must be injected into reservoir 10 to maintain an adequate pressure therein, additional lean gas may be injected through input well 12 from line 30 from an extraneous source, another portion of the reservoir, or the like. Similarly, water may be injected through line 31 and input well 12 in conjunction with, or in sequence with, the lean gas. Alternatively, a fluid such as water may be injected into the reservoir through an additional well, not shown in the figure. Such a well, for example, might be one located down dip from output well 11.

While the embodiment of the invention described above and illustrated in the drawing constitutes the best mode contemplated for carrying out the invention, it will be apparent that various modifications may be practiced without departing from the spirit of the invention. Thus, some of the produced oil may be burned or cracked, on occasion, to generate sufficient lean or rich gas fractions for the practice of the invention. For example, some or all of the lean gas fraction may be burned with air to produce additional quantities of gas for injection into reservoir 10 through well 12. Such a gas would not, of course, ordinarily be as miscible with the solvent slug 24 as would the lean gas itself. However, such a gas could be injected into the reservoir after a substantial volume of lean gas itself had been injected. While such a gas might not be entirely miscible with the slug 24, it would be completely miscible with the lean gas.

Thermal or catalytic cracking of the produced oil, or a component thereof, could be used to generate additional quantities of both lean gas and rich gas fractions.

While the separation zone 14, as previously noted, is shown to be a single unit, various forms and combinations of apparatus may be employed for this purpose. A conventional arrangement, for example, is to use a 200 to 300 p.s.i. separator followed by a 50 p.s.i. separator. In such an arrangement, lean gas would be taken as the overhead fraction from the first separator, and the rich gas fraction as the overhead fraction from the second separator. Equipment of this type is frequently employed in the field to remove casing head gas from produced oil. Conventional gasoline distillation equipment, including fractionators and the like, may also be employed as desired.

The contacting zone 15 may consist of one or more conventional packed towers, bubble plate towers, or the like suitable for use in contacting gases and liquids. Any lean gas not absorbed by the residual oil upon contact of these two materials in zone 15 may be recycled to compressor 18.

Reservoir 10 shown in the drawing does not have a gas cap; and in such a reservoir the enriched gas and lean gas fractions are preferably injected into the uppermost portions of the crest of the reservoir.

In those instances where a reservoir has a gas cap, the enriched gas fraction is preferably injected substantially at the interface between the gas cap and the reservoir oil. The miscible slug formed by the injection of such fraction is thereby located at the interface. The lean gas fraction may subsequently be injected behind the slug.

The invention may be practiced using any suitable number and arrangement of wells. However, it is generally preferred, as indicated earlier, to select well patterns which tend to minimize fingering tendencies of the miscible slug.

Depending on the composition of the enriched gas fraction and the manner in which it is separated from the residual oil fraction, the former fraction may, on occasion, be in either the gaseous phase or the liquid phase at various points in the process of this invention. Thus, the compressor **20** in some instances may be replaced by a pump.

As pointed out earlier in this description, it is desired in the practice of the present invention to maintain the miscible slug employed therein in a single fluid phase with both the reservoir oil and the gas used to drive the slug. Accordingly, the invention is especially adapted for use in reservoirs capable of operation at the pressures required for such operation. Operation at lower pressures is possible to the extent ordinarily that the miscible slug and the drive gas can be permitted to exist with a phase interface therebetween. While such a system is effective in improving the recovery of oil from a reservoir, it has the disadvantage of requiring larger quantities of drive gas than in the case where the drive gas and the slug materials form a single phase.

To recapitulate briefly, the present invention relates primarily to an improved gas-propelled, slug-type, miscible displacement process wherein said slug and said gas have compositions such that they form a single fluid phase with one another at said reservoir temperature and under the operating reservoir pressure used to conduct such process. The composition of the slug is also selected such that it forms a single fluid phase upon contact with said reservoir oil at the temperature of the reservoir and the operating pressure. Conversely, of course, the selection of the operating pressure may depend to some extent on the compositions that are possible for the slug and the propelling gas.

In a first stage of the process, crude oil is produced from a reservoir and fractionated at the surface of the earth so as to obtain a fraction comprising a mixture of hydrocarbons which upon contact with reservoir oil at the temperature of the reservoir and the reservoir operating pressure will form a single fluid phase with such oil. This mixture in most cases will comprise hydrocarbons containing from 2 to 4 carbon atoms—i.e., hydrocarbons which are normally gaseous at atmospheric temperature and pressure (14.7 p.s.i.a. and 70° F.) but liquefiable at atmospheric temperature. This mixture of hydrocarbons, upon separation from the produced reservoir oil, is reinjected into the reservoir through an input well spaced sufficiently from the point of production so as to form a bank of the mixture within the reservoir in the vicinity of the input well

Also during the first stage of the process, at least a portion of the remaining produced reservoir oil (including any gas) is reinjected into the reservoir through a second input well which is spaced from the first input well and also from the point of production so as not to interfere with the bank of hydrocarbons formed at the first input well, and also so as to not be re-produced from the reservoir until some time during the second stage of the process.

During the first stage of the process, additional pressurizing fluid may be injected into the reservoir—again at a point remote from both the point of production and the first input well—as may be necessary to maintain the desired operating pressure. The pressurizing fluid may generally be any petroleum fraction, such as may be derived from other parts of the reservoir in question or from an entirely different reservoir. It may also be water, inert gases such as producer gas, gases of combustion (as, for example, produced by burning natural gas), natural gas, nitrogen, carbon dioxide, and the like.

The first stage of the process is completed when the bank of hydrocarbons formed about the input well has reached the desired size—generally between about 5 and 15 percent of the hydrocarbon pore volume of the reservoir (or the portion of the reservoir to be processed). The second stage of the process then begins by injecting the propelling gas into the reservoir through the input well so as to drive the bank toward a spaced output well. Reservoir oil displaced by the bank and the propelling gas is recovered from the reservoir through the output well. The propelling gas is obtained from the recovered reservoir oil by any suitable separation technique, as described earlier. The seperation is conducted such that the gas has a composition enabling it to form a single fluid phase upon contact with a mixture of hydrocarbons contained in the bank at the temperature of the reservoir and the operating pressure.

During the second stage of the process, pressurizing fluid once again may be injected as necessary into the reservoir so as to maintain the reservoir at the desired operating pressure. This pressurizing fluid may be injected through the same input well as the propelling gas so long as it does not interfere with the single fluid phase relationship desired between the propelling gas and the hydrocarbon bank. Thus, if water is injected through the input well, it is preferred that slugs of water be injected such that propelling gas—and not water—will normally be in direct contact with the hydrocarbon bank.

What is claimed is:

1. A method of recovering oil from an underground reservoir which comprises the steps of producing oil from the reservoir to the surface of the earth through an output well, separating the produced oil into a light gaseous fraction, a residual oil fraction, and an intermediate fraction, such that said fractions have compositions whereby said intermediate gaseous fraction will form a single fluid phase with said reservoir oil and also with said light gaseous fraction under the temperature and pressure conditions within said reservoir, injecting said intermediate fraction into said reservoir through an input well spaced from said output well, injecting at least a portion of said residual liquid oil into said reservoir at a point removed from said output well and said input well, also injecting at least a portion of said light gaseous fraction into said reservoir at a point spaced from said output well and said input well, discontinuing the injection of said light gaseous fraction, said intermediate fraction, and said residual oil fraction after enough of said intermediate fraction has been injected to form a bank thereof within said reservoir adjacent said input well, and thereafter injecting said light gaseous fraction into said reservoir through said input well to drive said bank away from said input well, and recovering oil displaced from said reservoir by said bank at a point displaced from said input well.

2. A method as defined in claim **1** wherein said portion of said residual oil fraction is contacted with said light gaseous fraction prior to injection into said reservoir.

3. A method as defined in claim **1** wherein additional fluid other than said light gaseous fraction, said intermediate fraction and said residual oil fractions is injected into said reservoir during said method as may be necessary to maintain said reservoir pressure.

4. A method of recovering oil from a subterranean reservoir which comprises the steps of: producing reservoir oil from said reservoir to the surface of the earth through an output well, fractionating said produced oil into a lean gas fraction, a residual oil fraction, and a rich gas fraction, said rich gas fraction having a composition such that it forms a single fluid phase with said reservoir oil under the pressure and temperature conditions prevailing within said reservoir, injecting said rich gas fraction into said reservoir through a first input well spaced from said output well, injecting at least a portion of said residual oil fraction into said reservoir through a second input well spaced from said output well and said first input well, continuing the injection of said residual oil fraction and said rich gas fraction into said reservoir until the rich gas fraction thus injected is sufficient to form a bank of said rich gas fraction in said reservoir in the vicinity of said first input well, thereafter ceasing the injection of said residual oil fraction and said rich gas fraction, and injecting a fluid into said first input well so as to drive said bank of said rich gas fraction toward an output well spaced from said first input well.

5. A method as defined in claim 4 wherein said fluid comprises said lean gas fraction.

6. A method as defined in claim 5 wherein said rich gas fraction comprises liquefied petroleum gas and said lean gas fraction comprises natural gas, and said reservoir is maintained at a pressure sufficient to cause said rich gas fraction to form a single fluid phase with said lean gas fraction and said residual oil fraction at the temperature of said reservoir.

7. A method of recovering oil from a subterranean oil reservoir which comprises the steps of: producing reservoir oil from said reservoir to the surface of the earth through an output well, separating said reservoir oil into a first fraction comprising hydrocarbons containing between 2 and 4 carbon atoms, a second fraction containing materials boiling below said first fraction, and a third boiling above said first fraction, said first fraction having a composition such that it exists in a single fluid phase upon contact with said reservoir oil at the pressure and temperature conditions prevailing within said reservoir, injecting said first fraction into said reservoir through a first input well spaced from said output well, injecting at least a portion of said third fraction into said reservoir through a second input well spaced from said output well and said first input well, continuing the injection of said first and said third fractions into said reservoir until the amount of said first fraction thus injected is sufficient to form a bank of said first fraction within said reservoir adjacent said first input well, thereupon discontinuing the injection of said first and said third fractions, injecting a fluid into said first input well so as to drive said bank toward a production well spaced from said first input well, and recovering the reservoir oil from said production well.

8. A method as defined in claim 7 wherein said fluid comprises said second fraction, and wherein said reservoir pressure is maintained sufficiently great to cause said second fraction and said first fraction to exist as a single fluid phase upon contact at said reservoir temperature.

9. A method as defined in claim 8 wherein said reservoir pressure is maintained by the injection into said reservoir of fluids in addition to and other than said first, second and third fractions.

10. A method of recovering oil from a subterranean oil reservoir which comprises the steps of: producing reservoir oil from said reservoir to the surface of the earth through a production well, separating from said reservoir oil a fraction comprising hydrocarbons boiling between about −85° C. and 0° C. at atmospheric pressure, said fraction being adapted to have a composition such that it exists in a single fluid phase with said reservoir oil under the pressure and temperature maintained within said reservoir, injecting said fraction into said reservoir through a first input well spaced from said production well, injecting at least a portion of the remainder of the produced reservoir oil through a second input well spaced from said production well and said first input well, continuing the injection of said fraction and said remainder of said produced oil into said reservoir until the amount of said fraction thus injected is sufficient to form a bank of said fraction in the vicinity of said input well, thereafter ceasing the injection of said fraction and said remainder of the produced reservoir oil, and injecting a fluid into said first input well so as to drive said bank of said fraction toward an output well spaced from said first input well, and recovering oil from said output well.

11. A method as defined in claim 10 wherein said fluid comprises natural gas separated from oil recovered from said reservoir through said output well.

12. A method as defined in claim 11 wherein the pressure maintained within said reservoir is sufficient to cause said natural gas and said hydrocarbons to exist in a single fluid phase upon contact at the temperature of said reservoir.

13. A method as defined in claim 12 wherein water is injected into said first input well in addition to natural gas.

14. A method as defined in claim 10 wherein said fraction comprises hydrocarbons containing from 2 to 4 carbon atoms.

15. A method as defined in claim 10 wherein said fluid comprises a fraction of said produced reservoir oil which boils below said fraction.

16. In a method of producing oil from an underground reservoir by a gas-propelled, slug-type miscible displacement process wherein said slug comprises hydrocarbons which are normally gaseous but liquefiable at atmospheric temperature, the improvement which comprises starting said process by producing oil from said reservoir through an output well, separating a mixture of said hydrocarbons from said produced oil such that said mixture will form a single fluid phase with said reservoir oil at the temperature and pressure of said reservoir, injecting said mixture into said reservoir through an input well spaced from said output well so as to form a bank of said mixture in said reservoir in the vicinity of said input well, injecting at least a portion of the remainder of said produced oil into said reservoir and also injecting such additional pressurizing fluid into said reservoir as may be necessary during the injection of said mixture and said produced oil to maintain said reservoir pressure.

17. In a method of recovering oil from an underground oil reservoir by means of a gas-propelled slug-type miscible displacement process wherein said slug comprises hydrocarbons which are normally gaseous but liquefiable at about 70° F., the improvement which comprises: in a first stage of said method forming said slug by producing reservoir oil from said reservoir to the earth's surface through a first well, separating a mixture of said hydrocarbons from said produced reservoir oil which has a composition such that said mixture is completely miscible with said reservoir oil at the temperature and pressure maintained within said reservoir, injecting said mixture into said reservoir through an input well spaced from said first well in a quantity sufficient to form a slug of said mixture within said reservoir about said input well, in a second stage of said method injecting a propelling gas into said input well to force said slug toward a spaced output well, and recovering oil displaced by said slug through said spaced output well, said propelling gas being obtained by separating from the recovered oil a gaseous fraction which will form a single fluid phase with said mixture of hydrocarbons at the temperature and pressure conditions of said reservoir but which will form separate fluid phases with said reservoir oil at such conditions, injecting sufficient pressurizing fluid into said reservoir during said first and second stages to maintain said reservoir pressure, said pressurizing fluid during said first stage including at least a portion of said produced reservoir oil remaining after the separation of said mixture of said hydrocarbons, said portion being injected into said reservoir at a point remote from said input well and said first well.

18. In a method of recovering oil from an underground oil reservoir by means of a gas-propelled slug-type miscible displacement process wherein said slug comprises hydrocarbons containing from 2 to 4 carbon atoms, and wherein said method is operated at a reservoir pressure such that the propelling gas forms a single fluid phase with said hydrocarbons, the improvement which comprises: forming said slug in a first stage of said method by producing reservoir oil from said reservoir to the earth's surface through a first well, separating a mixture of said hydrocarbons from said produced reservoir oil of a composition such that said mixture forms a single fluid phase upon contact with said reservoir oil at said reservoir

temperature and said operating pressure, injecting said mixture into said reservoir through a first input well spaced from said first well in a quantity sufficient to form a slug of said mixture within said reservoir about said first input well, injecting at least a portion of the remainder of said produced reservoir oil into said reservoir through a second input well spaced remotely from said first well and said first input well, injecting such additional pressurizing fluid into said reservoir during said first stage as may be necessary to maintain said operating pressure, discontinuing the injection of said mixture of said hydrocarbons upon the formation of said slug, and thereafter in a second stage of said method recovering reservoir oil from said reservoir through an output well spaced from said first input well, separating a gaseous fraction from the reservoir oil recovered during said second stage which is of a composition such that it will form a single fluid phase with said mixture of hydrocarbons upon contact with said mixture of hydrocarbons at said reservoir temperature and said operating pressure, injecting said gaseous fraction into said reservoir through said first input well so as to drive said slug toward said output well, and injecting such additional pressurizing fluid as may be necessary into said reservoir during said second stage as may be necessary to maintain said operating pressure.

19. A method as defined in claim **18** in which said first well is the same as said output well.

20. A method of recovering oil from an underground oil reservoir which comprises the steps of producing oil from the reservoir to the surface of the earth through an output well, separating said produced oil into a light gaseous fraction, an intermediate gaseous fraction, and a residual oil fraction such that said intermediate gaseous fraction has a composition whereby it is completely miscible with said reservoir oil under the temperature and pressure conditions existing within said reservoir, injecting said intermediate gaseous fraction into said reservoir through an input well spaced from said output well in a quantity sufficient to establish a bank of said intermediate fraction within said reservoir, injecting at least a portion of said residual oil fraction into said reservoir at a point remote from said output well and said input well, also injecting at least a portion of said light gaseous fraction into said reservoir at a point remote from said output well and said input well, discontinuing the injection of said intermediate gaseous fraction, said residual oil fraction, and said light gaseous fraction upon the formation of said bank, thereafter injecting at least a portion of said light gaseous fraction through said input well into said reservoir so as to cause said bank to displace oil from said reservoir, and injecting such pressurizing fluid as may be necessary into said reservoir during said first and second stages to maintain the pressure within said reservoir such that said light gaseous fraction and said intermediate gaseous fraction will form a single fluid phase upon contact with one another at said reservoir temperature and said pressure.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,223,157 December 14, 1965

James W. Lacey et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 3 and 4, for "assignors, by mesne assignments, to Esso Products Research Company, a corporation of Delaware" read -- assignors, by mesne assignments, to Esso Production Research Company, of Houston, Texas, a corporation of Delaware --; line 13, for "Esso Products Research Company, its successors" read -- Esso Production Research Company, its successors --; in the heading to the printed specification, lines 5 and 6, for "Esso Products Research Company, a corporation of Delaware" read -- Esso Production Research Company, Houston, Tex., a corporation of Delaware --.

Signed and sealed this 7th day of March 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents