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RECOVERY OF OIL BY MEANS OF ENRICHED GAS INJECTION

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ABSTRACT OF THE DISCLOSURE

A single-well injection-production scheme is used to reduce heavy oil or tar viscosity with propane-methane mixtures. Propane concentration is kept below the asphalt-precipitation level. Propane is kept close to the well so as to minimize losses and increase flow in this critical region. Injection cycles of propane injection and oil production can be staggered so that gas produced from one well may be injected into another. A hydrocarbon well wash may be used prior to injection of propane-methane. Butane may be used. Field data are given showing increased production and viscosity reduction.

The present invention relates to a novel recovery method for producing petroleum from an underground reservoir thereof. Preferably it is concerned with a one well cyclic process for the recovery of petroleum having an API gravity no greater than about 30° from a reservoir having a medium to relatively low energy content. However, the process is also applicable where a substantial pressure differential already exists within the reservoir but flow rates are below those desired due to the highly viscous nature of the petroleum.

Briefly, the process of our invention involves injecting an enriched gas, such as a mixture of natural gas and propane, at an elevated pressure into a formation containing an oil or tar. This mixture is forced into the formation for a time sufficient to permit contacting the native crude with a certain volume of enriched gas. This volume of enriched gas is a relative matter depending upon the type of operational procedure to be employed in actual field application. Two potential operating techniques include the injection of very substantial volumes of enriched gas ranging from a few million to several hundred million standard cubic feet into the formation in the vicinity of the well. However, in other cases the injection of a relatively small volume ranging from several thousand to a few million standard cubic feet will accomplish the intended objectives of utilizing this process. The technique to be employed in any field application will be determined based on an analysis of such things as immediate and continued supply of solvent and carrier gas, along with the desire and ability to handle an intermittent or continuous injection program. In this way the viscous oil or tar is contacted with a suitable solvent at a relatively low concentration such that the solvent dissolves in the oil on contact and substantially reduces the viscosity of the oil. The resulting oil solution is then able to flow toward the well and be produced with the pressure drop available whereas at the higher original viscosity prior to treatment, the oil flow rate was much lower or even zero. After the gas-solvent injection step the system is subjected to a soaking period

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extending from zero time to several days after which the well is placed on production. Some wells treated by this method have produced over extended periods of time, i.e., from about two months to one year, at a rate of from about two to ten times that prior to treatment. Once the producing rate decreases substantially, for example, its producing rate prior to treatment, the above cycle can be repeated.

In a typical petroleum reservoir the primary depletion energy is usually adequate to maintain a satisfactory oil production rate until a relatively large portion of the oil-in-place has been produced. Secondary recovery operations ordinarily consist of fluid injection into certain wells in an attempt to displace additional oil from the reservoir area located between the injection and producing wells. This is true, for example, in the case of any displacement mechanism employed in secondary and/or tertiary recovery operations. There are many reservoirs, however, saturated with low gravity, highly viscous oil. Generally speaking, these crudes are also undersaturated so that production resulting from the primary depletion mechanism is short-lived and associated primary producing rates are usually quite low due to the high oil viscosity. Of even greater importance, however, is the fact that, due to the nature of these crudes, a complete spending of the inherent energy sources leaves an extremely large percent of the original oil-in-place still within the reservoir. Well to well or interwell secondary recovery methods using fluid injection processes are not particularly adaptable to this type of reservoir owing to the low mobility of oil located in the region near the producing well. This results in low oil recovery rates even in the presence of a larger driving force that has been created in the interwell area because of fluid injection. Conventional waterflooding in these reservoirs has been mostly unsuccessful from an overall recovery efficiency viewpoint because of the unfavorable mobility ratio that exists between the displacing and displaced phases.

In the past a number of single well injection production schemes have been proposed to overcome the difficulties encountered in attempting to produce oil from reservoirs of the above-mentioned type. One approach has been to employ a cyclic steam injection process which usually involves a soaking period between the injection and production stages. This method does result in heating the formation around the wellbore, thus decreasing the viscosity of the oil. While this technique has experienced limited success, the heat losses occurring impose rather severe restrictions on the depth and pay thickness that can be treated. For example, it is considered uneconomic to employ steam at depths in excess of 3,000 feet because of excessive heat losses and the pay thickness of any prospect should be at least 30 feet. Also investment costs for equipment are very substantial and operating costs in terms of dollars per barrel of recovered oil are such that a valid question exists regarding the economical attractiveness of this type operation in many cases of current application.

Previously the use of hydrocarbon solvents for the extraction of heavy oils or tars from the formation containing them has been considered, but after some study was felt to be impractical. Thus, in his report entitled "The Development of the Alberta Bituminous Sands," published in 1950 for the Alberta Provincial Government, S. M. Blair states (page 46) that the solvent extraction of tar sands in place has been proposed. He further points out solvents, such as the light hydrocarbons were tested but found to be unsatisfactory because the yield of de-asphalted oil amounted to only 56 percent and that "Variations in the propane to oil ratio, or in the extraction temperature had no measurable effect on the yield of gas oil from the bitumen."

In Canadian Patent No. 603,924, a method is described for recovering viscous oils by means of a secondary recovery method wherein a normally gaseous hydrocarbon or stream comprising an admixture of normally gaseous hydrocarbons is injected into the reservoir. In this process it is essential that the normally gaseous hydrocarbon or stream possesses a critical temperature sufficiently low such that the critical temperature of the hydrocarbon is lower than the temperature of that portion of the formation containing the viscous oil undergoing treatment and into which the gaseous hydrocarbon is injected. Hydrocarbons in the C_1 to C_4 range are listed as suitable for use in such secondary recovery method. However, it is evident from the disclosure of the Canadian patent that under these conditions the hydrocarbon or hydrocarbon mixture which contacts and dissolves in the crude oil, results in concentrations of solvent (ethane) which far exceed the amount that causes precipitation of asphalt. For example, this reference teaches the use of an injection fluid consisting of 75% ethane and 25% methan and/or propane. In this connection, we have experimentally determined that when liquid ethane is mixed with a tar or heavy crude oil at 60° F. and 600 p.s.i., an ethane-rich liquid containing a small amount of the light ends of the tar or crude oil is formed. The bulk of the tar or oil is left as a separate phase in the form of a semi-solid or solid material. When ethane vapors contact a tar or heavy crude the same phase behavior occurs, the only difference being that a third phase of ethane vapor is present. In the above-mentioned Canadian patent it is apparent the inventor did not appreciate the fact that his diclosure placed the process in a range of fluid mixtures where substantial precipitation of solid material occurs. This of course tends to plug a porous rock formation and makes the process impractical. The Blair experiments with propane, referred to above, illustrate this same point.

It is accordingly an object of our invention to provide a single well injection-production method by the use of a carrier gas enriched with a solvent for crude oil or tar whereby increased production of said well can be sustained over extended periods of time. It is another object of our invention to provide a means whereby conditions are such that precipitation of asphalt present in the heavy crude or tars subjected to our novel recovery method is avoided. It is still another object of our invention to provide a solvent mixture capable of reducing the viscosity of the oil or tar to a greater extent than any single component of said mixture. It is a further object of our invention to provide a cyclic single well injection-production method for the recovery of heavy oils or tars at depths much greater than those to which steam injection is applicable. It is still a further object of our invention to provide a method involving enriched gas solvent mixtures, such as contemplated herein, whereby said mixtures are injected into one well penetrating the heavy oil reservoir, allowed to contact said oil during the injection and shut in periods, thereafter producing the well, separating the gas phase from the produced fluids, next injecting said gas phase into a second well penetrating said reservoir and repeating therein the sequence of steps carried out in the first well.

Before a detailed discussion of the present invention is undertaken we wish to point out that the benefits contemplated by Canadian Patent 603,924 can only be achieved by working at the opposite end of the injection fluid composition range taught by the aforesaid patent and also by Blair, in order to prevent the precipitation of solid material. This may be illustrated with phase behavior data we have obtained for mixtures of propane and Athabasca tar. Such mixtures were made and mixed intermittently and samples of the solution drawn off for an analysis to test solubility of tar and liquid propane at 90° F. and 500 p.s.i.a.

TABLE I

Wt. percent tar in total mixture:	Wt. percent tar in solution
5.7	4.2
15.9	9.2
31.6	20.5
50.6	41.5
62.3	60.3

These data show that as solvent concentration in the total mixture is decreased the mixtures approach homogeneity (no precipitation of solids) where solvent concentration is about 40 wt. percent or less. This behavior has been shown to be quite general with propane, butane, pentane and methane-propane mixtures, with Athabasca tar and other low gravity crude oils, in that precipitation of large amounts of solid material occurs when solvent concentration in the tar or heavy oil phase approaches 40 wt. percent.

In another series of tests, samples of Four Bear Field (Wyoming) crude oil having an API gravity of 13.5°, were mixed with different volumes of propane, after which the entire mixture in each case was passed through a filtering medium at 130° F. and 500 p.s.i.a. The amount of solids on the filter was collected and weighed. The results obtained from analysis of each sample are shown in the table below:

TABLE II

Wt. percent propane in crude oil—C_3 mixture:	Wt. percent solids—precipitated
27.5	0
53.0	2.2
60.3	4.1
61.4	5.1
71.4	9.0
79.4	13.6

From an inspection of the results in the above table it is again shown that precipitation occurs as the concentration of solvent in the crude oil approaches 40 wt. percent. Thus, the key to a successful recovery process is based on the concept of contacting the heavy oil or tar in place in such a manner that only limited amounts of solvent can dissolve in the oil. Such a concept is completely lacking in the above-mentioned Canadian patent and the report by Blair, referred to above.

The process of our invention is based primarily on the fact that the heavy oils or tars can be reduced substantially in viscosity without asphalt precipitation and thus be produced in the form of a readily flowable solution. For example, we have found that Athabasca tar which has a viscosity of about 100,000 centipoises at 90° F. yields solutions—at this same temperature—having viscosities ranging from 4 to 30 centipoises when 30 to 20 weight percent propane, respectively, is dissolved therein. Crude oil having a viscosity of about 290 centipoises can be reduced to a viscosity of about 170 centipoises by dissolving only 2.3 weight percent propane in the oil at 150° F. and 165 p.s.i. Tests on crude from the East Velma Field in Stephens County, Okla., and having a viscosity of 18.2 centipoises showed that its viscosity could be reduced to 3.5 centipoises by contacting the oil with a 12 wt. percent propane and methane mixture and to 1 centipoise or less by a mixture of enriched gas containing on the order of 20 wt. percent propane. Four Bear (Wyoming) crude having a native viscosity of 362 centipoises can be reduced to less than 1 centipoise with a 40 wt. percent propane mixture. Calculations indicate that Jobo crude in Venezuela having a native viscosity of several thousand centipoises can be reduced a hundredfold or greater by the addition of propane in the form of an enriched gas.

This reduction in viscosity increases as the concentration of solvent increases up to the limits where asphalt precipitation occurs. Where solvents of the type contemplated herein are employed, asphalt precipitation usually takes place when the solvent content of the resulting solution exceeds about 40 weight percent. Generally speaking, light hydrocarbons, such as ethane, are considered impractical as solvents in carrying out our invention since such materials have to be handled at considerably higher pressures to achieve the same solubility in crude oil as is obtained with propane. In the case of butane, only lower concentrations could be maintained in the carrier gas phase at a given pressure compared with propane. We have found, however, that in the case of a 65–35 mixture of propane and butane, the viscosity of heavy oil was reduced substantially more than was possible with the same total concentration of either pure propane or pure butane.

For the purpose of interpretation of the present description and claims, gas-solvent mixtures as used herein will be referred to as "enriched gas." As previously mentioned, the amount of solvent present in the petroleum solution depends both on the oil as well as the solvent. However, we have found that in no instance should the solvent be present in the carrier gas in a concentration that will result in more than about 40 weight percent solvent in the crude oil. This holds true whether the solvent is propane, butane or pentane or a mixture of two or more of these materials; however, the proximity of solvent concentration in the crude oil to 40 weight percent will, of course, vary slightly with the temperature and the specific solvent or solvent mixture used. For a given solvent, the amount that can be used to form the "enriched gas" employed in the recovery of a given oil or tar without causing asphalt precipitation can be readily determined by means of a simple experiment.

Prior to treating a well in accordance with our invention we preferably inject a volume, for example, 50 to 100 barrels of natural gas condensate liquid to wash away any accumulation of wax or asphalt that might be plugging perforations and hindering gas injectivity. The gas-solvent mixture injected in the manner contemplated herein would, to a degree, accomplish the same result although somewhat more slowly. After this initial cleanup of the formation face, the injected solvent serves to keep the wax dissolved in the produced oil and it does not cause asphalt precipitation until relatively high concentrations of solvent are present. Thus, no further solids precipitation problems interfere with the process once it is in operation.

One of the outstanding features of our invention is that in one of its preferred embodiments it is carried out as a one well operation. The carrier gas plus solvent, i.e., enriched gas, is injected into the well for a relatively short time after which injection is stopped and the well kept shut in for a brief "soaking period," ranging from a few minutes to several days, if convenient or desired. Thereafter the well is placed on production. This type of operation has a number of distinct advantages, such as (1) maximum contacting of the oil with the enriched gas is accomplished close to the producing well; (2) the solvent required, although cheaper than crude oil, is not always abundant and cheap, and by keeping it in the formation relatively close to the producing well its use is maximized and there is less likelihood of losing large quantities of it to unknown sections of the reservoir where its effectiveness may be questionable at best; (3) the backflow of the carrier gas imposes a hydraulic gradient on the diluted oil and causes it to flow to the well. Many reservoirs where this process of our invention will find application are those which have relative low reservoir pressure conditions and only traces of gas present. Under such reservoir conditions as a temperature under 130° F. and at a reservoir pressure less than 100 p.s.i.g., a crude of 15° API gravity or less, will scarcely flow at all.

Our process has the further advantage in permitting maximum solvent usage—together with minimizing the quantity required—by arranging injection and production cycles of wells in a field so that the gas (enriched gas) produced from one well can be injected into another well extending into the same reservoir. In following this procedure, the injection and production cycles may be the same length. This gaseous effluent or "enriched gas," obtained usually from a separator, frequently contains more solvent than was present in the initially injected mixture. Accordingly, the composition of this effluent which is to be reinjected should be carefully controlled so that asphalt precipitation is avoided. Regulation of the reinjected enriched gas can be accomplished through proper pressure control of the gas-oil separator and further addition of carrier gas or enriching component.

It will be seen that an operation of this type is more independent of the solvent supply and price conditions. In any event, these possible variations permit freedom to optimize an operation in terms of the specific characteristics of a given well. For example, our invention may be carried out at injection pressures ranging from a few hundred p.s.i. up to about 1200 or 2000 p.s.i. The injection pressure ideally employed should be such as to promote fingering of the enriched gas over a wide area of the reservoir in the vicinity of the well but not so much as to establish direct and continuous communication with offset wells that are not associated with the recovery process. Fingering is important in that the distribution, size, and extension of these fingers will determine the effectiveness of this process in contacting the native crude, and the more effectively the oil is contacted with the enriched gas the greater will be the volume of oil that is reduced in viscosity and which can be produced more readily. In some cases, when a well is placed on production it may produce nothing but enriched gas for a day or so. This will depend mainly upon the magnitude of the injected volume of enriched gas. It is primarily due to the relatively high gas saturation that is created within the immediate vicinity of the well bore during the injection phase. However, upon initiation of the producing cycle, the pressure drop across the reservoir is reversed and the well bore becomes a pressure sink as compared to the reservoir pressure located some radial or linear distance away from the well bore. This means reservoir fluid movement will begin toward the well bore under the influence of the reservoir pressure gradient which includes a localized super-charged effect resulting from the injection phase. Oil production will then begin depending upon the magnitude of the injected gas volume and the gas saturation that exists near the well bore at the time the well is placed on production. Following the establishment of oil productivity, the gas-oil ratio will continue to decrease to a certain level and then remain relatively constant over an extended period of time. This is a definite characteristic of the process of our invention, particularly in the case of large injected volumes of enriched gas. The amount of solvent or daily rate produced with the oil after the first few days of the producing cycle will generally be relatively small. A typical value represents about 3 or 4 volume percent (includes solvent produced in liquid and gaseous phases) of the produced oil and will remain at that level over an extended period of time. Actual well performance has indicated that propane concentrations in the separator oil and gas phases during the producing cycle following stabilization will be approximately twice the prestimulation normal propane concentration levels. These performance data indicate very good contacting and dispersion of the injected gas into the crude oil during the preceding injection and soaking steps. The uniform rate at which the propane has been returned during the producing cycle is also indicative of the length of time or life to be expected from the producing cycle. The rate and total quantity of injected gas can be varied, depending on the well conditions under consideration. In this regard, the principal factor that should be controlled is the concentration of the solvent in the resulting oil solution. Such concentration, of course, should always be below that which causes asphalt precipitation. In the case of propane, a typical injection mixture is 10 to 30 percent propane and 90 to 70 percent natural gas. In some instances the initial gas injection rate is low, e.g., injection of 3 million SCF of natural gas and 380 barrels of propane required a period of eight days. This is frequently because the oil saturation around the well is high. As subsequent cycles reduce the oil saturation, higher injection rates are possible. Ordinarily we prefer to employ the highest injection rates possible—without fracturing the formation—since this forces the gas further out into the reservoir, thus contacting more oil in a shorter time and minimizing nonproductive time. The process of our invention will be further illustrated by the following specific examples.

Example I

A well located in the East Velma Field, Stephens County, Okla., having a perforated zone from 5975 feet to 5995 feet and producing about 7 barrels of 26 API° gravity oil per day was subjected to the process of our invention in accordance with the following procedure. A total of about 50 barrels of natural gas condensate liquid was introduced into the formation via the aforesaid perforations at an injection pressure of 1250 p.s.i. The injection period lasted for approximately fourteen days. Initially, it was difficult to inject this mixture into the formation presumably due to high liquid saturation near the well bore. At the end of the injection period, however, a total of 2.1 million cubic feet of enriched gas containing about 198 barrels of propane were introduced into the formation. Thereafter, this mixture was allowed to soak in the oil bearing zone for one day following which the well was placed on production yielding a peak rate of 71 barrels of oil per day and finally after about sixty-nine producing days settled to its original production of 7 barrels per day. During this period the gas-oil ratio ranged from about 3,000/1 to about 2,000/1. Over this period of time 436 barrels (varying in API gravity from 27° to 19°) of additional oil (bonus oil) were recovered. A propane material balance was made on the fifty-first day after the well was placed on production and the ratio of bonus oil to unrecovered injected propane was found to be 6.0.

The second cycle was started by first injecting a natural gas-propane mixture for a period of four days at a pressure of 1250 p.s.i. This corresponded to 3.04 million cubic feet of enriched gas containing 471 barrels of propane. After this mixture was injected, it was allowed to soak in the formation for three days, and at the end of this time the well was again placed on production. At the beginning of this cycle the well produced 61 barrels of oil per day and required 34 producing days before production again settled to the original level of 7 barrels per day. During this time 205 barrels of bonus oil were produced yielding approximately 1.86 times more oil by the use of this treatment than would have otherwise been produced.

The third injection cycle was started by injecting 500 barrels of natural gas liquid condensate into the oil bearing zone followed by 1,000 MFC of 2,000 p.s.i.g. dry gas. After the completion of this injection cycle, the well was returned immediately to production. The initial post-stimulation producing rate was 112 barrels of oil per day and after 34 days the well is still producing above the 7 BOPD prestimulation rate. During this time an average cycle rate of 20 barrels of oil per day has been realized while producing some 419 barrels of new oil. The nature or gravity of the produced oil has averaged 28 to 30° API as compared to a normal range for this well of 19 to 21° API. Condensate appears to have a greater effect on API gravity than enriched gas due to its liquid-liquid mixing qualities.

In production histories taken for the initial cycles of operation on this well it is significant that favorable and repeatable results were secured with small volume injection treatments. The second major point to be made is that clearly a cyclic process was demonstrated resulting solely from the energy input into the native reservoir system. The decline of the peak rate back to normal prestimulation values indicates that viscosity reduction and expansion of input energy are the dominant features of utilizing this process on a continuing basis as opposed to well bore cleanout effects which is a positive factor in those cases where production does not decline back to prestimulation values. A different solvent additive and operating procedure i.e., composition of solvent and liquid phase entry into the oil bearing zone followed by dry gas injection to attain the desired contacting and dispersion effect with the native crude was employed during the third cycle on this well and attained the desired results available from the utilization of this process.

It is also to be pointed out that one of the features of utilizing this process is an increase in API gravity of the produced crude which amounts to an incremental gain in value of the produced oil depending directly upon the magnitude of the increased gravity.

Example II

In a second well in the same field as reported in Example I, perforations extending opposite a pay zone from 5032 feet to 5150 feet were first washed with 50 barrels of natural gas condensate liquid after which a mixture of natural gas and propane was injected into the formation via the aforesaid perforations at an injection pressure of about 1,250 p.s.i. This injection operation covered a period of nineteen days during which time a total of 40.2 million feet of enriched gas containing 5,000 barrels of propane were introduced into the formation. Following the injection step, the well was shut in and the system permitted to soak for three days. When the well was placed on production, substantial volumes of gas were producing during the first seven days reaching a peak rate on the seventh day of .875 million cubic feet per day. Thereafter gas production subsided and the oil rate increased over a twenty-one day period from the original 50 barrels per day rate to 120 barrels per day. After this treatment, it was impossible to keep the produced fluid pumped out of the well, and ten months after the aforesaid soaking period, the well was producing 120 barrels of oil per day ranging in gravity from about 24° to about 27.6 API° gravity. Prior to treatment, the well produced 50 barrels of 24 API° gravity oil per day. It is also of interest to note that after 232 producing days, 7,787 barrels of bonus oil has been recovered along with 2,350 barrels of propane or about 51 percent of that originally injected. Further, it should be noted that at the end of the above-mentioned ten-month period, propane production was only about 3 to 4 barrels a day indicating that the current cycle at high producing oil rates could be expected to continue for an extended period. Some 313 days after producing cycle No. 1 began—following treatment—there has been produced 12,151 barrels of bonus oil with the total being increased daily at a producing rate maximum of approximately 140 barrels.

The significant results of utilizing relative large volume treatments include the long term stabilized post-stimulation rate and the relatively uniform rate at which the solvent was returned in the separator gas stream. The latter consideration is particularly important where plans are to be made for a continuous utilization of the produced solvent.

The data indicate a minimum rise in API gravity of three degrees throughout the life to date of producing cycle No. 1.

While we are not certain why increased oil recovery rates are obtained by the application of our invention, we believe the principal factors responsible for these favorable results are the marked reduction in viscosity and the energy added to the reservoir. Injection of dry gas alone has not shown any appreciable increase in oil production. Also, location of the well on a particular portion of the structure is important because the fluid characteristics vary as a function of structure. In certain cases operation near the gas-oil contact has resulted in undesirably high gas-oil ratios. The increased gas production apparently occurs because the injected gas fingers through to the gas cap and thus creates permeability paths.

It will be apparent to those skilled in the art that numerous modifications to the above-described procedure may be made without departing from the scope of our invention. Thus, for example, it is conceivable that the effectiveness of this process could be increased even more if during its entire operation the reservoir pressure throughout the field was maintained at some elevated level by injection of carrier gas or fluids into wells not participating in the cyclic process. This would serve to provide more energy for the backflow period or producing cycle for production of lower viscosity crude than is available from the limited amount of carrier gas injected in the cycle as described above. In place of natural gas it should be pointed out that the carrier gas could be flue gas—or its equivalent—which may be generated more cheaply.

We claim:

1. In a method for recovering petroleum from an underground reservoir thereof penetrated by a well, the improvement which comprises injecting a petroleum solvent enriched gas into said reservoir via said well, permitting the injected enriched gas to contact said petroleum away from said well to reduce the viscosity thereof without the formation of objectionable amounts of an asphalt-containing precipitate, discontinuing injection of said gas and shutting in said well to allow for a soaking period of variable time, placing said well on production and thereafter producing therefrom said petroleum of reduced viscosity, said enriched gas containing said solvent in a concentration that results in not more than about 40 weight percent solvent in the petroleum thus produced.

2. The method of claim 1 in which the solvent employed in said enriched gas is propane and it is present therein in an amount such that the concentration of said propane in the resulting petroleum solution thereof is not more than about 40 weight percent

3. The method of claim 1 wherein the solvent employed is a mixture of propane and butane.

4. The method of claim 1 in which the gas employed is flue gas.

5. The method of claim 4 in which the solvent employed is propane.

6. The method of claim 1 in which the sequence of steps defined therein is repeated.

7. In a method for recovering petroleum from an underground reservoir thereof penetrated by two wells, the improvement which comprises injecting a petroleum solvent enriched gas into said reservoir via one of said wells, permitting the injected solvent enriched gas to contact said petroleum away from said one of said wells to reduce the viscosity thereof without the formation of objectionable amounts of an asphalt-containing precipitate, discontinuing injection of said enriched gas and then placing said one of said wells on production, thereafter producing therefrom said petroleum of reduced viscosity, separating a gas phase containing said solvent from the petroleum thus produced, injecting said solvent-containing separated gas phase into said reservoir via the other of said wells, discontinuing injection of said separated gas and allowing the injected solvent enriched gas to contact petroleum away from said other of said wells to reduce the viscosity thereof again without the formation of objectionable amounts of an asphalt-containing precipitate, placing said other of said wells on production and thereafter producing therefrom said petroleum of reduced viscosity, said enriched gas and said separated gas containing said solvent in a concentration that results in not more than about 40 weight percent solvent in the petroleum thus produced.

8. The method of claim 3 wherein the propane and butane are employed in an approximate ratio of 65% to 35%.

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