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(57) The present invention refers to the use of solvents such as light liquid fractions of petroleum, for example diesel oil and gas oil, a light petroleum, and the essential oils derived from renewable sources such as for example biodiesel, used pure or mutually admixed in any proportion, for injection into a geological formation through an injection well, there resulting a final mixture (petroleum/injected solvent) presenting much lower viscosity and much greater fluidity than the original petroleum, having an impact throughout the petroleum production chain. The present patent presents real gains in all phases of the production chain.

Product	HEALTH AND ENVIRONMENT					PERFORMANCE		
	NFPA			Observations	ISPO		Viscosity	
	Life	Fire	Reactivity		Volatility	Vapour pressure	Apparent	Dynamic
1 Turpentine	3	3	1	ND	moderate	36.6 mmHg (37.8 °C)	1.15 cSt (25 °C)	
2 Light aromatic extract	3	3	1	carcinogenic and mutagenic	low	ND	167 mPa (20 °C)	ND
3 Heavy aromatic extract	3	2	1	carcinogenic and mutagenic	low	ND	ND	23.37 cSt (20 °C)
4 Standard petrol	1	4	1	ND	very high	0.50 kgf/cm ² (17.8 °C)	0.38 mPa	ND
5 Hexane	1	3	1	ND	high	160 hPa	0.376 mPa (20 °C)	0.45 cSt (25 °C)
6 Naphtha from schist	2	4	1	ND	very high	ND	ND	ND
7 Petrochemical naphtha	1	4	1	ND	very high	35 hPa	0.54 mPa (20 °C)	ND
8 Basic white oil 72	0	1	1	carcinogenic	low	ND	ND	14.1 cSt (27.8 °C)
9 Basic light naphthenic acid oil - NAb 20	0	1	1	carcinogenic	low	< 5 mmHg (25 °C)	ND	26.3 cSt (140 °C)
10 Basic light hydrogenated naphthenic oil - HNL	0	1	1	carcinogenic	low	< 5 mmHg (25 °C)	ND	3.5 cSt (140 °C)
11 Basic light neutral oil PNL 30	0	1	1	carcinogenic	low	< 5 mmHg (25 °C)	ND	18.5 cSt (140 °C)
12 Diesel oil	0	2	1	ND	moderate	ND	5.2 mPa (20 °C)	2.5 - 5.5 cSt (140 °C)
13 Basic naphthenic lubricating oil 20	0	1	1	carcinogenic	low	< 5 mmHg	ND	2.7 - 10.7 cSt (140 °C)
14 Petroleum 1-SCS-10A-BSS	1	3	1	ND	low	ND	4.5 mPa (20 °C)	ND
15 Kerosene	1	3	1	ND	moderate	5 mmHg (38 °C)	1.29	1.3 cSt (140 °C)
16 Aromatic residue	2	3	1	carcinogenic	low	ND	ND	45.50 (188.9 °C)
17 Toluene	2	3	1	ND	high	38 mmHg (20 °C)	ND	0.55 cSt (20 °C)
18 Xylene	2	3	1	ND	high	< 10 mmHg	ND	0.74 cSt (25 °C)

ISPO = Chemical products safety information database

NFPA = National Fire Protection Association

FIG. 1**EP 1 939 393 A1**

DescriptionField of the invention

5 **[0001]** The present invention refers to a sustainable method for increasing the recovery of petroleum from petroleum-bearing subterranean formations, particularly formations wherein petroleum is found as oil which is too viscous to flow or be pumped.

[0002] More particularly the present invention refers to a method of recovery (extraction) of petroleum from the original geological formation utilising injection of diesel and/or biodiesel oil through the injection well, reducing the viscosity of the petroleum, dissolving heavier and immobile petroleum fractions and traversing the reservoir acting through the sweeping and displacement effectiveness, increasing oil recovery and the proven reserve.

Background of the invention

15 **[0003]** In view of the increasing need for energy one of the great challenges of the petroleum industry worldwide is achieving maintenance of production to satisfy current demands.

[0004] The model currently followed aims to maintain production and reserves through the discovery of new accumulations; although such approach has in general led to the discovery of new offshore accumulations, they are frequently found at great depths in increasingly-deep water and frequently in deposits wherein the oil found is of high viscosity.

20 **[0005]** The association of viscous oil, great depths and maritime environment results in enormous technico-operational complexity and high production costs and said scenario affects technical and economic effectiveness and production sustainability.

[0006] Environmental sustainability under such conditions is also a critical matter, principally with reference to the collection and disposal of fluids.

25 **[0007]** Thus the great challenges for the petroleum industry in Brazil and worldwide are maintenance of production, to maintain self-sufficiency, and replacement of reserves, to ensure sustainable future supply, being understood as socio-environmentally responsible.

[0008] Furthermore in various parts of the world diverse petroleum-bearing geological formations are found wherein only conventional methods of petroleum recovery are used, however others cannot be fully exploited using such methods because the oil contained in such formations is too viscous to flow or be pumped.

30 **[0009]** As a consequence thereof another important aspect of the current model is the fact of large investments being made in prospection in the search for new reserves without appropriately exhausting those already being worked and still containing a large volume of remaining oil, signifying the disrespectful extraction of a natural resource without concern for future generations.

35 **[0010]** Therefore increasing the working life of a field is directly related with the currently-available techniques of Enhanced Petroleum Recovery (EPR), the methods hitherto employed solely taking into consideration immediate technical and economic effectiveness without great attention being paid to socio-environmental aspects.

[0011] According to the literature there exists a series of chemical additives having the objective of viscosity reduction and of relatively-restricted application, normally employed as a method of stimulation in production wells to eliminate formation damage or as an additive in cyclic steam-injection processes (injection/production in production wells). In a broader sense such products do not satisfy technical, economic and environmental requirements in the manner herein proposed by the present invention.

Related art

45 **[0012]** The use of solvents is already known and widely employed for the dilution of viscous oils, the objective whereof being to facilitate transport within wells or in production lines or even volumetric oil transfer.

[0013] The use of solvents in petroleum production has been restricted to or concentrated in countries wherein geological formations are found having ultraviscous oils and very low ambient temperatures, such as Venezuela and Canada, in the form of well stimulation, injection/production through the production well.

50 **[0014]** In general the currently-existing technology having this objective has been solely concerned with the technical and economic effectiveness of the processes employed and thus the solvents employed heretofore cause environmental disequilibrium, both on the surface, having consequences for the ecosystem and mankind, and within the environment of the geological reservoir, causing chemical, physical, physico-chemical and biological disequilibrium in said environment.

55 **[0015]** Utilisation of substances classified as environmentally-damaging in the diverse methods hereunto known has shown that said substances were selected taking into consideration solely availability and cost to the detriment of environmental matters, which substances have thus become the target of increasing questioning by environmental

entities in various parts of the world, reflecting a new philosophy in society.

5 [0016] United States patent US 6 279 653 discloses that the viscosity of heavy oils may be significantly reduced converting such oil into a stable microemulsion. Such microemulsion is formed combining alkaline reagents with the oil and subjecting the same to ultrasonic energy. Said reduction in oil viscosity permits the oil to be pumped out of the well and it may then be conveyed for refining, however introducing extraneous substances into the environment of the geological formation, which same require to be removed from such oil 1 through particular procedures, in addition to the utilisation of ultrasound.

10 [0017] United States patent US 5 025 863 discloses a process for well stimulation (injection/production in the production well) wherein a slug of immiscible natural gas is injected into a formation through the production well. The well is then shut in for a given time ('soak period') for the gas to enter solution. The well is then put into production when petroleum is then produced together with the gas utilising conventional production equipment and techniques, however the fact of struggling with gas and injecting the same through the production well raises other questions in terms of safety and effectiveness of the procedure.

15 [0018] United States patent US 6 491 053 refers to a known manner of reducing the viscosity of heavy petroleum through admixing the same with a liquid component of lower density. Said component may be petrol, kerosene or other components such as to better pump the oil. At its destination the solvent added may be removed and recycled. This procedure is expensive and when crude petroleum requires pumping over long distances recirculation of the viscosity-reducing agent becomes complicated. This is a process to ensure flushing pipelines and lines, it is not a method for recovering petroleum which acts within the reservoir.

20 [0019] United States patent US 4 531 586 also discloses a process for cyclic stimulation of heavy oil production in a petroleum reservoir comprising injection (through the production well) into the reservoir of a liquid solvent such as diesel oil or a light petroleum and production of the oil/solvent admixture. This is a method of well stimulation, injection and production in the production well having a reduced scope, not being an enhanced petroleum recovery method.

25 [0020] United States patent US 3 127 934 refers to the injection of two slugs of solvents through the injection well. The first slug comprises solvents of low molecular weight, specifically gases (C1 to C4) which as the author discloses dissolve the oil contacted effectively, however it has a great tendency to pass around the regions bearing oil creating preferential channels, that is to say the gases tend to seek regions of high permeability. The second slug comprises solvents or other types of material which, in contact with water, polymerise forming a product blocking the region washed. This is a different concept, involving plugging regions of high permeability. In both cases referred to the use of gases involves very delicate situations in terms of operational and safety matters, and as to the materials which polymerise, these may also prevent some areas of interest in the formation being prevented from subjection to more efficient washing.

30 [0021] Once the natural energy of a reservoir has been exhausted it is normal to commence secondary recovery, that is to say injection of water or gas as displacing fluids. The effectiveness of the process is low because such fluids have a tendency to create preferential channels in regions or beds of high permeability.

35 [0022] The degree of formation of such preferential channels is determined by several factors of which the most important is the ratio between viscosity of the petroleum to be recovered and viscosity of the fluid injected.

40 [0023] A manner of minimising formation of such preferential channels is to seek to more closely approximate the viscosities of the 'displacing' and 'displaced' (petroleum) fluids. One option is the addition of polymeric additives to injection water (displacing phase) to increase the viscosity thereof. The second option is to reduce the viscosity of the petroleum through the use of miscible fluids.

[0024] In many cases wherein the oil is of high viscosity the process of secondary recovery ends by being abandoned because the oil can no longer be economically produced due to the high ratios of water injection to oil produced.

45 [0025] When working with an oil of high viscosity, should the expected water injectivity into the reservoir not be achieved, the normal practice is injection of steam into the formation with the objective of improving the extraction flow of the oil, acting in a general manner on the production well which, in a petroleum context, represents stimulation of the production well.

[0026] In general approximately 30% of the petroleum is recovered through conventional Primary and Secondary recovery processes. Thus 70% of all the original petroleum still remains in reservoirs and this is therefore the target of Tertiary Recovery, also known as Enhanced Petroleum Recovery (EPR).

50 [0027] Such cost-effectiveness is however a function of the effectiveness of recovery techniques, investment wherein has been put aside due to investment in new discoveries. Investment in such techniques signifies extending the working life of a field and recovering in a respectful manner a non-renewable natural resource.

55 [0028] Thus in spite of advances in the art there still exists a requirement for an Enhanced Petroleum Recovery process, either for normal exploitation or even for better utilisation of the oil contained in a geological formation, thus increasing the working life of a reservoir.

Summary of the invention

5 [0029] The present invention presents a method of Enhanced Petroleum Recovery combining general, economic, environmental and social effectiveness in order to increase the recovery factor of onshore or offshore fields, more precisely through the use of a miscible substance for use in reservoirs, having the objective of reducing viscosity and fluidifying the petroleum. Such substance is selected from the group consisting of diesel oil or fractionated gas oil from petroleum, or even biodiesel, being similar and derived from plants, or light oil, which products may be utilised pure or with additives, in an isolated manner or together with other fluids or methods such as: steam, polymers, etc. Such substances, subject of the present patent, require to be highly-miscible with the oil contained in the geological formation wherein it is intended to act, injection being executed through the injection well and traversing the entire reservoir to the production well, which in the petroleum context represents Enhanced Petroleum Recovery (EPR).

10 [0030] For the purposes of the present invention solvent is understood to be biodiesel or oil, having characteristics similar to the diesel habitually produced from mineral sources, being produced however from renewable sources, normally agricultural sources.

15 [0031] More specifically the present invention refers to the use of solvents such as light liquid petroleum fractions, for example diesel oil or gas oil, a light petroleum, and essential oils derived from renewable sources such as, for example, biodiesel, used in a pure form or in a common admixture in any proportion for injection into a geological formation through the injection well, resulting in a final admixture (petroleum/injected solvent) having a much lower viscosity and much greater fluidity than that of the original petroleum, impacting on the entire petroleum production chain. The present invention presents a real advantage in all phases of the production chain:

- 20 1) increase in recovery factor;
- 2) increase in proven reserves;
- 3) reduction in loss in lifting and transport;
- 25 4) elimination of the necessity for using additives to render paraffinic oil viable;
- 5) adjustment of oil viscosity to refining conditions plus, in the case of solvents derived from petroleum, their recovery and it being possible to return them to the process or be marketed.

30 [0032] The method of the present invention is especially indicated for utilisation when petroleum is of high viscosity or paraffinic and/or the formation is of low permeability, resulting in conditions wherein the petroleum possesses low fluidity characteristics throughout the formation.

35 [0033] Thus the use of diesel and/or biodiesel and the other products recommended in the present invention is indicated for petroleum of the paraffinic type, being the case of some occurrences of petroleum of the paraffinic type in Brazilian territory, or even for petroleum in low-temperature environments or which require to be transported under the rigours of such environments.

[0034] The present invention may also be employed for the displacement of immovable reserves of petroleum of the asphaltenic type wherein a small addition of aromatics to the diesel extraction charge greatly enhances the positive results with said technique.

40 [0035] In this context such diesel and/or biodiesel is not to be considered primordially as a solvent fluid but should be interpreted as being a fluid whose utilisation is indicated due to it being miscible with the petroleum found in the reservoir, and not be considered as a substance extraneous to the environment wherein it is applied, in addition to also satisfying other requisites of a technical, environmental and economic nature, as aforesaid.

45 [0036] An objective of the present invention is to provide a sustainable method of recovery by means of which significant quantities of oil may be extracted from a reservoir bearing petroleum of low fluidity through reduction in viscosity of said viscous oil with the objective of improving flow within the reservoir and pumping conditions.

[0037] Another objective of the present invention is to provide an improved process by means of which additional quantities of oil may still be recovered from reservoirs containing oil of low fluidity, principally those reservoirs which have already been normally treated by water and/or steam flooding and which in many cases would now be considered as being exhausted, wherein the procedure occurs by means of injecting into such geological formation, containing said petroleum of low fluidity, the miscible fluid referred to, such recovery being realised without requiring injection of excessive quantities of fluid miscible with the petroleum within the reservoir and which same is pushed throughout the extent of the reservoir by means of a displacing fluid such as, for example, water.

50 [0038] A further objective of the present invention is to provide a process of recovery by means of which an oil of low fluidity may be recovered from geological formations in a shorter time through the injection of smaller quantities of fluid and in more favourable ratios of oil to injected fluid than are possible through application of presently-known processes.

55 [0039] By virtue of diesel being homogeneously miscible with petroleum and both the diesel and the petroleum/diesel solution possessing relatively low densities and viscosities, flow throughout the formation is thus stimulated and the process of the present invention renders recovery possible in locations heretofore considered difficult and inefficient or

even costly or impossible.

[0040] A yet further relevant aspect of the method of the present invention is that the fluid miscible with the oil contained in the formation rather than being injected through the production well is injected into the geological formation through the injection well resulting in the solvent traversing the formation from the injection well to the production well and, as a function of the difference in viscosity between the miscible fluid, lying in the intermediate band between water and the oil, it acts in a decisive manner on the effectiveness of displacement through the reduction in viscosity and dissolution of the heavier fractions of the oil impregnated in the formation and on the sweeping effectiveness.

[0041] Enhanced Petroleum Recovery, together with Secondary Recovery, always presuppose an injected (displacing) phase with the objective of displacement of the oil.

[0042] In this manner the method of the present invention has a yet further consequence of its mechanism of acting, being a significant improvement in displacement effectiveness and sweeping effectiveness within the geological petroleum-bearing formation, being the two key points of attack of the methods of Enhanced Petroleum Recovery.

[0043] Thus the final recovery factor is a function of the effectiveness of the displacing phase, being:

(i) Sweeping Effectiveness, associated with viscous forces or the difference in viscosity between the displacing/displaced (petroleum) phases; and

(ii) Displacement Effectiveness, associated with the effectiveness of driving or displacement of the oil from the swept area, combined with capillary forces.

[0044] Such characteristics are of operational importance insofar as their acting conjointly contributes to more homogeneous distribution of capillarity, preventing preferential routes through the subject formation, in addition to preventing separation along the route traversed by the drive fluid.

[0045] A further important aspect is that the method of the present invention may be applied employing the same devices and equipment utilised for secondary recovery, injection of water and/or steam, at the pressure and the temperatures of the environment of the geological formation to be treated.

Brief description of the figures

[0046]

Figure 1 presents a table referring to the survey of technical, economic and environmental data of a number of viscosity reducers available in the Brazilian market.

Figure 2 presents a graph showing the reduction in viscosity following utilisation of a number of substances utilised as viscosity-reducing agents.

Detailed description of the invention

[0047] The present invention refers to the injection of liquid petroleum fractions, the classification of such petroleum fractions according with the number of carbons in the chain, as shown in Table I below.

TABLE I	
REFINERY PRODUCT	HYDROCARBON BAND
Gas	C ₁ - C ₄
Petrol	C ₅ - C ₁₀
Kerosene	C ₁₁ - C ₁₈
Diesel	C ₁₄ - C ₁₈
Heavy gas oil	C ₁₂ - C ₂₅
Lubricating oil	C ₂₀ - C ₄₀
Residue	> C ₄₀

[0048] Within this phase we emphasise the band of hydrocarbons from C₁₄ - C₁₈ corresponding to diesel being that

presenting the most suitable technical and environmental effectiveness. The liquid fractions ($C_5 - C_{13}$) prior to those of diesel ($C_{14} - C_{18}$) also offer technical effectiveness, however as the number of carbons in the chain decreases vapour pressure increases and, flowing therefrom, environmental risks also increase. In addition, in the liquid fraction having a number of carbons exceeding fourteen ($> C_{14}$), as the number of carbons in the chain increases, always being linear, environmental effectiveness increases and technical effectiveness diminishes. For application in heavier oils, generally containing significant levels of asphaltenes, a small fraction of an aromatic solvent such as xylene or toluene should be admixed with the viscosity reducers subject of this patent to prevent precipitation of asphaltenes.

[0049] Injection of gas to increase the recovery yield of oils of high viscosity is already known, being classified as conventional recovery.

[0050] In accordance with the Table presented in Figure 1 and taking into consideration the objective of working in a sustainable manner, that is to say prioritising social and environmental responsibility, the first criterion for the evaluation of viscosity reducers has been that of the least environmental impact which they might cause.

[0051] In this manner in this initial selection all those which presented a high negative environmental impact were rejected, even in detriment to their technical advantages. Among the same there were also eliminated naphtha, C_5^+ , petrol, and the aromatic extract.

[0052] Also in conformity with the Table shown in Figure 1, diesel oil, a light petroleum represented here by oil from a specific well (Petrobrás, Brazil), turpentine and kerosene presented the least negative environmental impact, that is to say less toxicity, less danger, less risk of explosion than the other solvents due to having lower vapour pressures than the others.

[0053] In the specific case of the aromatic extract and similar products, in spite of not having a high vapour pressure like the others referred to, they present a high degree of toxicity due to their carcinogenic and mutagenic characteristics.

[0054] From among the viscosity reducers approved, those having least economic cost were diesel oil and analysed light oil proceeding from said well (Petrobrás, Brazil). The interpretation of this analysis is consolidated in the Table presented in Figure 1.

[0055] In a second stage the products selected, that is to say diesel oil and the light oil because they presented least environmental impact and least cost, were evaluated in accordance with their rheological performance, viscosity reduction, based on admixtures having diverse proportions of the solvent and the viscous oil from the Nativo Oeste field (Petrobrás, Brazil), on which were executed measurements of dynamic viscosity. Said analyses were compared with others executed on the same oil and other solvents under the same conditions, confirming the technical potential of said selected viscosity reducers. The results are shown in graph form in Figure 2.

[0056] Thus diesel oil and the light oil were approved in the environmental, technical and economic context as viscosity-reducing agents, however diesel oil was found to be best in terms of the viscosity drop obtained as a function of the proportion of petroleum.

[0057] Thus far the products were analysed and approved in an isolated manner, that is to say merely as viscosity-reducing agents. A further application for such substances was considered taking as a basis not solely their viscosity-reducing power but, in addition, the interaction thereof with the formation and their mechanism of action as a method of Enhanced Petroleum Recovery.

[0058] For operational purposes with reference to facilitating pumping conditions for lifting and transporting in pipelines the oil produced, this latter should possess a viscosity lower than 300 cP, preferably lower than 250 cP, more preferably lower than 200 cP.

Description of the preferred embodiment

[0059] The understanding of Enhanced Petroleum Recovery (EPR) takes into consideration the concept of Secondary Recovery. The injection of water or gas (displacing fluids during Secondary Recovery) has as its purpose displacement of the (displaced) oil in the reservoir by means of purely-mechanical behaviour, that is to say on injecting water or on subjecting the reservoir to a process of immiscible gas injection it is not expected that there will be chemical or thermodynamic interaction of such fluids with the oil or with the rock. The fluid injected displaces the oil, occupying the pores vacated by the oil as the latter is expelled from the formation, however not the entire volume swept by the displacing fluid expels the oil. Such oil remaining in the regions invaded by the fluid injected is denominated residual and is a consequence of the effect of capillarity.

[0060] EPR and Secondary Recovery always presuppose an injected (displacing) phase having the objective of displacing the oil. The final recovery factor is a function of two aspects of effectiveness of such displacing phase: Sweeping Effectiveness, linked to viscous forces or the water/oil viscosity difference; and Displacement Effectiveness, linked to the effectiveness of driving the oil from the swept area, associated with capillary forces. Said two aspects define the points of attack of Enhanced Petroleum Recovery causing modifications to the physico-chemical and thermodynamic nature of the fluids and interactions between the same and the formation.

[0061] In order to act on Sweeping Effectiveness we require to increase the viscosity of the displacing phase or reduce

the viscosity of the displaced phase (petroleum) and to affect the Displacement Effectiveness it is necessary to act on the interfacial tension between the displacing and displaced fluids and/or the wettability of the fluids/rock system.

[0062] The novel concept herein presented proposes a method of Enhanced Petroleum Recovery based on the injection of a slug of diesel oil through the injection well of the formation followed by injection of water.

[0063] Such novel concept offers technical, economic, environmental and social contributions.

1) Technical: The mechanism of acting of the method is divided into two phases: the first during displacement of the slug of diesel oil through the formation and the second during the recommencement of water injection.

1.1) During displacement of said slug of diesel oil: the slug injected enters the formation in the regions of least resistance and reduces the viscosity of the petroleum contacted becoming incorporated into said slug of diesel oil, its viscosity increasing in proportion to the original quantities and viscosities of the components of the admixture (diesel oil and petroleum). This is the mechanism of acting on the Displacement Effectiveness of the method, that is to say solubilisation of the immovable oil, i.e. oil which would remain in the formation even following contact with injected water, rendering it mobile with consequent reduction in viscosity of such mobile oil.

1.2) During recommencement of water injection: the water front enters the formation contacting and displacing the oily phase (now petroleum/diesel oil) of lower viscosity than the previous phase (original petroleum). Said viscosity reduction of the displaced phase is translated into an increase in the Sweeping Effectiveness of the displacing phase due to reduction in the difference in viscosity between the displacing (water) and displaced (admixture) phases.

1.3) Additionally a wettability reversal (rock/oil to rock/water) may occur promoting even further displacement of the remaining oil by water injected subsequent to passage of the slug of diesel.

2) Environmental:

Upstream: Injection of the slug of diesel oil may be executed using the same water injection system already installed, however such system requires adaptation and certification in accordance with the Safety, Environment and Health (SEH) regulations and standards for handling inflammable substances.

In the formation: The method herein presented will not cause biochemical disequilibrium in a reservoir because from the chemical point of view said oil already forms part of the composition of the petroleum therefore the injection of diesel oil into a formation does not introduce substances extraneous to such formation. In the same manner disequilibrium will not arise in the biota of the formation given that the microorganisms existing therein are already adapted to this component, being one of the fractions of petroleum.

Downstream: As the product (viscosity reducer) used in this novel concept is an integral part of the petroleum and will be produced together therewith, the care required in this phase is identical to that already implemented for the petroleum.

3) Economic: As the diesel oil is a subproduct of the petroleum it has a cost being dependent on the price of petroleum and the processing for its obtainment therefrom. However, introduction of a mixture having approximately 20% diesel already significantly reduces the viscosity of the original petroleum to less than 300 cP, being sufficient to change an immovable into a movable oil. More precisely, in this case each barrel of diesel oil recovers four of petroleum and, in addition, the diesel oil extracted admixed with the petroleum may return to the process following normal processing of the recovered oil.

An economic alternative to the process wherein the price of diesel is not linked to the price of petroleum is the use of biodiesel rather than utilisation of diesel oil from petroleum. In this case a renewable source of energy would be being used for the extraction of a non-renewable natural resource, being attractive in terms of economic support for diverse agricultural regions in the world.

As well as diesel and/or biodiesel, gas oil or a light petroleum may be used.

The use of crude petroleum does not involve refining costs however it does not offer the same results in reduction of viscosity when compared with diesel.

Gas oil offers as an economic advantage over diesel one less process being hydrotreatment, thus the cost should be slightly less than that of diesel, however it also presents disadvantages in matters relating to Safety, Environment and Health (SEH).

4) Social: The great challenges for the petroleum industry in Brazil and worldwide are maintenance of production

to maintain self-sufficiency and replacement of reserves to ensure future supply with sustainability, that is to say environmental and social responsibility. Currently, to satisfy such demand companies are investing massively in new reserves exploration and particularly in Brazil the majority thereof are found in environments at great depth on the continental platform wherein the majority are constituted by heavy oils. Thus, as a consequence of the application of said operational strategy, a large quantity of oil, approximately 70% or more in onshore formations having all the support structure and in the majority of cases containing a light oil of excellent quality, now no longer require to be 'abandoned' due to a matter of economics, by virtue that the utilisation of the technique of the present invention greatly increases the possibilities of recovery, extending the working life of a formation, extracting natural assets in a respectful manner, taking into account the concern for future generations.

[0064] In this manner the addition of diesel oil and/or biodiesel provides the following economic advantages:

- it renders the extraction of heavy or ultraviscous oil possible or feasible;
- it increases the recovery factor reducing residual saturation;
- it contributes to the transport of petroleum in the lifting phase and flushing in pipelines in a general manner, principally in low-temperature environments;
- it increases the value of petroleum through viscosity reduction and raises its API grade, rendering such oil more suitable for marketing;
- it adjusts the petroleum for the most favourable refining conditions;
- the diesel and/or biodiesel injected is not lost, it is produced admixed with the oil and may be recovered during processing and be recycled once again into the flow to be injected through the injection well for continuation of the recovery process of high-viscosity petroleum.

[0065] In this manner the present invention is a method of Enhanced Petroleum Recovery combining technical, economic, environmental and social effectiveness to increase the recovery factor of onshore or offshore fields having a high level of exploitation, more precisely the use of solvent, diesel oil, biodiesel and other similar products, used separately or in conjunction with other fluids or methods such as steam, polymers, etc, its acting mechanism being improvement in Displacement Effectiveness and Sweeping Effectiveness, the two key points of attack of Enhanced Petroleum Recovery (EPR) methods.

[0066] In addition, application of the method of the invention permits rendering high-viscosity petroleum suitable for the operational conditions of lifting and transport by virtue of ensuring flushing in production wells, lines and pipelines.

Example

[0067] The example provided below presents a specific application of the invention to an oil produced in Brazil; due to the high-viscosity characteristics of the type of Brazilian paraffinic petroleum denominated Nativo Oeste (API-13, viscosity 3500 cP) the present invention was applied utilising a number of more-available substances having been tested with the objective of use as viscosity-reducing additives in the injection operation through injection wells in production activities.

[0068] The application of the present invention in the rheology determination tests with the objective of selecting a more appropriate viscosity reducer for use in the field to render viable steam injection into a formation through the injection well, led to the graph shown in Figure 2.

[0069] In accordance with Figure 2, diesel achieves the result of lowering viscosity from 3500 cP to less than 250 cP at concentrations of solely 15 - 20%, placing it in an advantageous position with respect to the other reducers analysed, taking into account the technical, economic and environmental parameters considered for the diverse solvents available in the Brazilian market.

[0070] More precisely we observe that for each barrel of diesel injected to treat said high-viscosity oil there exists the possibility of recovering approximately five barrels of petroleum from the reservoir due to the fact of injection of diesel oil achieving a reduction in the viscosity of the oil contained in the formation to approximately 250 - 300 cP.

[0071] In addition the diesel oil extracted admixed with said petroleum may be returned to the injection process following normal processing of the oil recovered by extraction.

[0072] The Table shown in Figure 1 shows the results with reference to the technical, economic and environmental data of the various solvents existing in the Brazilian market, taking into account the parameters relating to their Safety, Environment and Health (SEH) aspects.

[0073] Although the present invention has been presented in its preferred method of embodiment together with a specific example, it shall be understood that the same are merely provided illustratively and shall not be considered as limiting the spirit and scope of the present invention.

[0074] Those skilled in the art will be capable of determining the most economically-favourable percentages of utilisation

for application, based on the guidance herein presented, which shall be incorporated within the spirit and scope of the present invention.

[0075] In this manner modifications to the bands of application of diesel oil and/or biodiesel which may be made over and above those herein presented will be obvious to those skilled in the art. Such modifications shall be the subject of experimentation to bring about percentage increases in the desired recovery of high-viscosity petroleum, providing benefits from the technical and economic point of view in accordance with their nature and industrial purpose. However it is clear that such modifications are incorporated within the spirit and scope of the present invention.

Claims

1. A method for recovery of petroleum **characterised in** employing a viscosity-reducing agent for said petroleum contained in a formation to increase its fluidity, wherein such viscosity-reducing agent is injected into said formation through an injection well.
2. A method according to claim 1, **characterised in that** said viscosity-reducing agent comprises diesel oil.
3. A method according to claim 1 or 2, **characterised in that** said viscosity-reducing agent comprises biodiesel.
4. A method according to claim 1, 2 or 3, **characterised in that** said viscosity-reducing agent comprises light liquid fractions of petroleum.
5. A method according to any preceding claim, **characterised in that** said viscosity-reducing agent comprises light crude petroleum.
6. A method according to any preceding claim, **characterised in that** said viscosity-reducing agent comprises an admixture of diesel oil and biodiesel in any proportion.
7. A method according to any preceding claim, **characterised by** being employed in the recovery of high-viscosity paraffinic petroleum contained in such formation and/or high-viscosity asphaltenic petroleum contained in such formation.
8. A method according to any preceding claim, **characterised by** being utilised in secondary recovery at locations wherein water is not injected into such formation.
9. A method according to any preceding claim, **characterised by** increasing the economically useful life of a reservoir due to reduction in residual saturation.
10. A method according to any preceding claim, **characterised by** utilising essential oils preferably derived from renewable sources.
11. A method according to any preceding claim, **characterised in that** said viscosity-reducing agent comprises a mixture of essential oils preferably derived from renewable sources.
12. A method according to any preceding claim, **characterised in that** said viscosity-reducing agent is used in isolation or conjointly with other fluids such as steam, polymers and solvents.
13. A method according to any preceding claim, **characterised by** satisfying the norms of Safety, Environment and Health (SEH).
14. A method according to any preceding claim, **characterised in** adjusting such high-viscosity petroleum to operational conditions of lifting and transport, ensuring flushing of production wells, lines and pipelines.
15. A method according to any preceding claim, **characterised by** adjusting charges of high-viscosity petroleum to operational conditions in refineries.
16. A method according to any preceding claim which is a sustainable method and/or in which said viscosity-reducing agent must be injected into said formation through the injection well.

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	Product	HEALTH AND ENVIRONMENT					PERFORMANCE			
		NFPA			Observations	ISPQ		Viscosity		
		Life	Fire	Reactivity		Volatility	Vapour pressure	Apparent	Dynamic	
1	Turpentine	2	3	1	ND	moderate	36.8 mmHg (37.8 °C)		1.15 cSt (25 °C)	
2	Light aromatic extract	3	3	1	carcinogenic and mutagenic	low	ND	167 mPa (20 °C)	ND	
3	Heavy aromatic extract	3	3	1	carcinogenic and mutagenic	low	ND	ND	28.87 cSt at 100 °C	
4	Standard petrol	1	4	1	ND	very high	0.60 kgf/cm ² (37.8 °C)	0.39 mPa	ND	
5	Hexane	1	3	1	ND	high	160 hPa	0.326 mPa (20 °C)	0.45 cSt (25 °C)	
6	Naphtha from schist	2	4	1	ND	very high	ND	ND	ND	
7	Petrochemical naphtha	1	4	1	ND	very high	35 hPa	0.54 mPa (20 °C)	ND	
8	Basic white oil 72	0	1	1	carcinogenic	low	ND	ND	14.1 cSt (37.8 °C)	
9	Basic light naphthenic acid oil - NAL 20	0	1	1	carcinogenic	low	< 5 mmHg (25 °C)	ND	26.3 cSt (40 °C)	
10	Basic light hydrogenated naphthenic oil - NHL	0	1	1	carcinogenic	low	< 5 mmHg (25 °C)	ND	9.2 cSt (40 °C)	
11	Basic light neutral oil PNL 30	0	1	1	carcinogenic	low	< 5 mmHg (25 °C)	ND	28.5 cSt (40 °C)	
12	Diesel oil	0	2	1	ND	moderate	ND	5.2 mPa (20 °C)	2.5 - 5.5 cSt (40 °C)	
13	Basic naphthenic lubricating oil 10	0	1	1	carcinogenic	low	< 5 mmHg	ND	9.7 - 10.7 cSt (40 °C)	
14	Petroleum 1-SCS-10A-BSS	1	3	1	ND	low	ND	4.5 mPa (20 °C)	ND	
15	Kerosene	1	3	1	ND	moderate	5 mmHg (38 °C)	1.29	1.3 cSt (40 °C)	
16	Aromatic residue	2	3	1	carcinogenic	low	ND	ND	45 SSU (98.9 °C)	
17	Toluene	2	3	1	ND	high	38 mmHg (20 °C)	ND	0.55 cSt (20 °C)	
18	Xylene	2	3	1	ND	high	< 10 mmHg	ND	0.724 cSt (25 °C)	

ISPQ = Chemical products safety information database

NFPA = National Fire Protection Association

FIG. 1

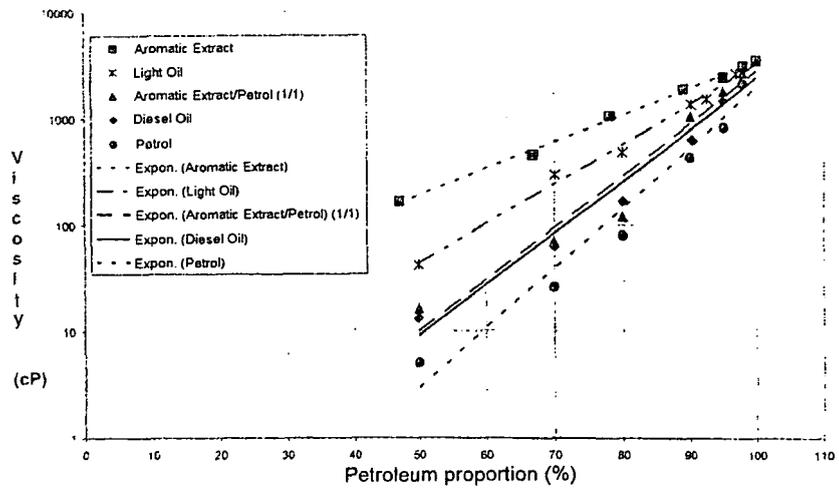


FIG. 2



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Munich		18 March 2008	Manolache, Iustin
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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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