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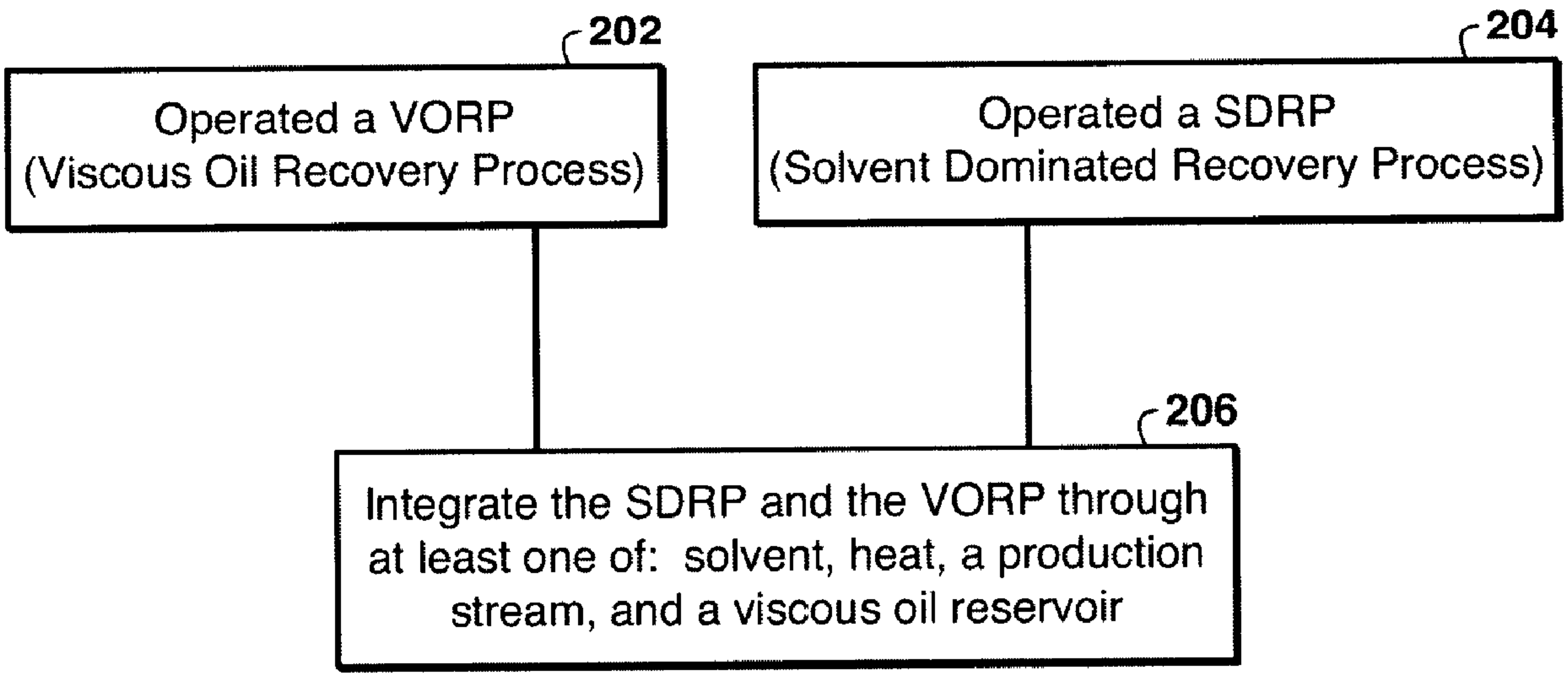


(57) Abrégé/Abstract:
The present disclosure relates generally to the integration of at least two viscous oil recovery processes (VORPs), at least one of which is a solvent-dominated recovery process (SDRP). Integration of the SDRP and the VORP may be achieved through at least one of: solvent, heat, a production stream, and a viscous oil reservoir.

ABSTRACT

The present disclosure relates generally to the integration of at least two viscous oil recovery processes (VORPs), at least one of which is a solvent-dominated recovery process (SDRP). Integration of the SDRP and the VORP may be achieved through at least one of: solvent, heat, a production stream, and a viscous oil reservoir.

INTEGRATION OF VISCOUS OIL RECOVERY PROCESSES

FIELD

[0001] The present disclosure relates generally to viscous oil recovery processes, for example processes for recovering bitumen from oil sands.

BACKGROUND

[0002] Oil sands are deposits comprising bitumen, clay, sand, and connate water, and make up a significant portion of North America's naturally-occurring petroleum reserves. Depending on the type and location of the deposit, bitumen may be extracted from mined oil sands, or recovered using an *in situ* process.

[0003] The term "viscous oil recovery process" (VORP) as used herein includes both *in situ* recovery processes and the extraction of bitumen from mined oil sand. Commercial *in situ* VORPs typically exploit at least one of temperature, pressure, and solvent to reduce the viscosity or otherwise enhance the flow of bitumen within the formation. Non-limiting examples of *in situ* VORPs include CSS (Cyclic Steam Stimulation), SAGD (Steam Assisted Gravity Drainage), SA-SAGD (Solvent Assisted-Steam Assisted Gravity Drainage), VAPEX (Vapor Extraction), LASER (Liquid Addition to Steam for Enhancing Recovery), SAVEX (Combined Steam and Vapor Extraction Process), CSD (Constant Steam Drainage), steam drive, solvent flood, FIRE (Fluidized *In Situ* Reservoir Extraction), and water flooding. An example of CSS is described in U.S. Patent No. 4,280,559 (Best). An example of SAGD is described in U.S. Patent No. 4,344,485 (Butler). An example of SA-SAGD is described in Canadian Patent No. 1,246,993 (Vogel). An example of VAPEX is described in U.S. Patent No. 5,899,274 (Frauenfeld). An example of LASER is described in U.S. Patent No. 6,708,759 (Leaute et al.). An example of SAVEX is described in U.S. Patent No. 6,662,872 (Gutek). An example of steam drive is described in U.S. Patent No. 3,705,625 (Whitten). An example of solvent flood is described in U.S. Patent No. 4,510,997 (Fitch). An example of FIRE is described in U.S. Patent Publication No. 2010/0218954 (Yale et al.).

[0004] As stated above, as used herein, a "VORP" may alternatively comprise the extraction of bitumen from mined oil sand (also referred to herein as a "mining" operation or process). A non-limiting description of certain oil sand extraction processes will now be provided. Oil sand extraction processes are used to liberate and separate bitumen from mined oil sand so that the bitumen can be further processed, for instance to produce synthetic crude oil. Numerous oil sand extraction processes have been developed and commercialized, many of which involve the use of water as a processing medium (referred to as aqueous-based extraction). Other processes are solvent-based processes. One aqueous-based extraction process is the Clark hot water extraction process (the "Clark Process"). This process typically requires that mined oil sand be conditioned for extraction by being crushed to a desired lump size and then combined with hot water (e.g. about 95°C) and perhaps other agents to form a conditioned slurry of water and crushed oil sand. In the Clark Process, an amount of sodium hydroxide (caustic) is added to the slurry to adjust the slurry pH upwards, which enhances the liberation and separation of bitumen from the oil sand. Other aqueous-based extraction processes may use other temperatures and may include other conditioning agents, which are added to the oil sand slurry, or may not use a conditioning agent. Regardless of the type of aqueous-based extraction process employed, the process will typically result in the production of a bitumen froth that requires treatment with a solvent. For example, in the Clark Process, a bitumen froth stream comprises bitumen, fine particulate solids (also referred to as mineral matter), and water. Certain processes use naphtha to dilute bitumen froth before separating the product bitumen, for instance by centrifugation. These processes are called naphtha froth treatment (NFT) processes. Other processes use a paraffinic solvent, and are called paraffinic froth treatment (PFT) processes, to produce pipelineable bitumen with low levels of solids and water. In the PFT process, a paraffinic solvent (for example, a mixture of iso-pentane and n-pentane) is used to dilute the froth before separating the product, diluted bitumen, for instance by gravity. A portion of the asphaltenes in the bitumen is also rejected by design in the PFT process and this rejection is used to achieve reduced solids and water levels. In both the NFT and the PFT processes, the diluted tailings (comprising water, solids and some hydrocarbon) are separated from the product diluted bitumen. Recovery of solvent from the diluted bitumen component is currently required before the bitumen may be delivered to a refining facility for further processing. An example of a PFT process is described in Canadian Patent No. 2,587,166 (Sury). Non-limiting examples of bitumen extraction from mined oil sand are described in U.S. Patent No. 7,585,407 (Duyvesteyn et al.), U.S. Patent Publication No. 2010/0147516 (Betzer-Zilevitch), and U.S. Patent Publication No. 2010/0276341 (Speirs et al.).

[0005] One type of *in situ* VORP is a solvent-dominated recovery process (SDRP). At the present time, solvent-dominated recovery processes (SDRPs) are not commonly used as commercial recovery processes to produce highly viscous oil. Highly viscous oils are produced primarily using thermal methods in which heat, typically in the form of steam, is added to the reservoir. Cyclic solvent-dominated recovery processes (CSDRPs) are a subset of SDRPs. A CSDRP is typically, but not necessarily, a generally non-thermal recovery method that uses a solvent to mobilize viscous oil by cycles of injection and production. Solvent-dominated means that the injectant comprises greater than 50% by mass of solvent or that greater than 50% of the produced oil's viscosity reduction is obtained by chemical solvation rather than by thermal means. One possible laboratory method for roughly comparing the relative contribution of heat and dilution to the viscosity reduction obtained in a proposed oil recovery process is to compare the viscosity obtained by diluting an oil sample with a solvent to the viscosity reduction obtained by heating the sample.

[0006] In a CSDRP, a viscosity-reducing solvent is injected through a well into a subterranean viscous-oil reservoir, causing the pressure to increase. Next, the pressure is lowered and reduced-viscosity oil is produced to the surface through the same well through which the solvent was injected. Multiple cycles of injection and production are used.

[0007] CSDRPs may be particularly attractive for thinner or lower-oil-saturation reservoirs. In such reservoirs, thermal methods utilizing heat to reduce viscous oil viscosity may be inefficient due to excessive heat loss to the overburden and/or underburden and/or reservoir with low oil content.

[0008] References describing specific CSDRPs include: Canadian Patent No. 2,349,234 (Lim et al.); G. B. Lim et al., "Three-dimensional Scaled Physical Modeling of Solvent Vapour Extraction of Cold Lake Bitumen", The Journal of Canadian Petroleum Technology, 35(4), pp. 32-40, April 1996; G. B. Lim et al., "Cyclic Stimulation of Cold Lake Oil Sand with Supercritical Ethane", SPE Paper 30298, 1995; US Patent No. 3,954,141 (Allen et al.); and M. Feali et al., "Feasibility Study of the Cyclic VAPEX Process for Low Permeable Carbonate Systems", International Petroleum Technology Conference Paper 12833, 2008.

[0009] The family of processes within the *Lim et al.* references describe embodiments of a particular SDRP that is also a cyclic solvent-dominated recovery process (CSDRP).

These processes relate to the recovery of heavy oil and bitumen from subterranean reservoirs using cyclic injection of a solvent in the liquid state which vaporizes upon production. The family of processes within the *Lim et al.* references may be referred to as *CSP*™ processes.

[0010] With reference to Figure 1, which is a simplified diagram based on Canadian Patent No. 2,349,234 (Lim et al.), one *CSP*™ process embodiment is described as a single well method for cyclic solvent stimulation, the single well preferably having a horizontal wellbore portion and a perforated liner section. A vertical wellbore (1) driven through overburden (2) into reservoir (3) is connected to a horizontal wellbore portion (4). The horizontal wellbore portion (4) comprises a perforated liner section (5) and an inner bore (6). The horizontal wellbore portion comprises a downhole pump (7). In operation, solvent or viscosified solvent is driven down and diverted through the perforated liner section (5) where it percolates into reservoir (3) and penetrates reservoir material to yield a reservoir penetration zone (8). Oil dissolved in the solvent or viscosified solvent flows into the well and is pumped by downhole pump through an inner bore (6) through a motor at the wellhead (9) to a production tank (10) where oil and solvent are separated and the solvent is recycled.

[0011] It would be desirable to improve at least one aspect of a current VORP.

SUMMARY

[0012] It is expected that certain SDRP projects may be near an existing and/or a future VORP. The present disclosure relates generally to the integration of at least two different viscous oil recovery processes (VORPs), at least one of which is a solvent-dominated recovery process (SDRP). Integration of the SDRP and the VORP may be achieved through at least one of: solvent, heat, a production stream, and a viscous oil reservoir.

[0013] In a first aspect, there is provided a method of operating at least two different viscous oil recovery processes, the method comprising: operating a solvent dominated recovery process (SDRP); operating a viscous oil recovery process (VORP); and integrating the SDRP and the VORP through at least one of: solvent, heat, a production stream, and a viscous oil reservoir.

[0014] Other aspects and features of the present disclosure will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Embodiments of the present invention will now be described, by way of example only, with reference to the attached Figures, wherein:

[0016] Fig. 1 is a schematic of a *CSP*™ process in accordance Canadian Patent No. 2,349,234 (Lim et al.).

[0017] Figure 2 is a flow chart outlining the integration of a SDRP with a VORP, according to a disclosed embodiment.

DETAILED DESCRIPTION

[0018] The term "viscous oil" as used herein means a hydrocarbon, or mixture of hydrocarbons, that occurs naturally and that has a viscosity of at least 10 cP (centipoise) at initial reservoir conditions. Viscous oil includes oils generally defined as "heavy oil" or "bitumen". Bitumen is classified as an extra heavy oil, with an API gravity of about 10° or less, referring to its gravity as measured in degrees on the American Petroleum Institute (API) Scale. Heavy oil has an API gravity in the range of about 22.3° to about 10°. The terms viscous oil, heavy oil, and bitumen are used interchangeably herein since they may be extracted using similar processes.

[0019] *In* situ is a Latin phrase for "in the place" and, in the context of hydrocarbon recovery, refers generally to a subsurface hydrocarbon-bearing reservoir. For example, *in situ* temperature means the temperature within the reservoir. In another usage, an *in situ* oil recovery technique is one that recovers oil from a reservoir within the earth.

[0020] The term "formation" as used herein refers to a subterranean porous media. The terms "reservoir" and "formation" may be used interchangeably.

[0021] As discussed in the background section, a CSDRP is one type of *in situ* VORP. Another description of a CSDRP is provided in Canadian Patent Application No. 2,688,392, filed December 9, 2009 (Lebel et al.).

[0022] As discussed in the background section, solvent-based extraction of mined oil sand is one type of VORP. An example of solvent-based extraction is provided in Canadian Patent Application No. 2,724,806 filed December 10, 2010 (Adeyinka et al.).

[0023] When referring to "SDRP", "CSDRP", "*in situ* VORP", "oil extraction of mined oil sand", or the like, this includes the associated facilities. To cite but one example, in a

CSDRP, the facilities for recovering solvent from the produced viscous oil and solvent are meant to be included in the scope of CSDRP.

[0024] As discussed in the summary section above, it is expected that certain SDRP projects may be near an existing and/or a future VORP. The present disclosure relates generally to the integration of at least two different viscous oil recovery processes (VORPs), at least one of which is a solvent-dominated recovery process (SDRP). Integration of the SDRP and the VORP may be achieved through at least one of: solvent, heat, a production stream, and a viscous oil reservoir. The expression "two different viscous oil recovery processes", means that the processes are different but may fall within the same category; for instance VAPEX and CSDRP are different processes, but fall within the SDRP category. While the integration may be more beneficial, in certain instances, when the two different processes are close to one another, proximity is not essential.

[0025] Certain underground viscous oil deposits, for instance certain Alberta oil sands, involve naturally occurring thick high oil saturation zones adjacent to lower oil saturation formations. The high oil saturation zones have historically been exploited first using thermal-solvent based in situ recovery methods. Thick high quality and deep deposits, too deep to be mined, are quite often surrounded by thinner and lower quality oil bearing zones. While viscous oil from the thick zones can be economically recovered by using thermal-solvent *in situ* recovery methods, the same processes would provide uneconomic yields in the thin lower quality zones due to excessive heat loss. Generally non-thermal SDRPs, can be employed effectively in many of those poorer quality reservoirs. In the future, SDRP projects may be developed next to existing thermal in situ operations when the poorer quality deposits are accessed. By integrating two different VORPs (for instance which are close to each other), it may be possible to improve energy use, to reduce infrastructure, to combine product streams (for instance two nearby operations), and/or to apply a hybrid recovery scheme (for instance to increase oil and solvent recoveries).

[0026] A similar trend also exists between mineable and shallow oil sand deposits (for instance 100 to 200m burial depth), such as in the Athabasca oil sands in Alberta. Thermal in situ methods such as SAGD and CSS may not be suitable in the shallow deposits due to fluid leakage to surface, and the absence of dissolved methane, respectively. Historically, the mineable deposits were developed first using surface mining combined with aqueous and other separation methods. In the future, if the shallow deposits, too deep for mining, are developed using non-thermal in situ solvent-based recovery methods, surface mining processing facilities may be located next to solvent-based in situ projects. By integrating two different operations (for instance two nearby operations), it may be possible to improve energy use, recycle by-production, and/or reduce infrastructure.

[0027] In one embodiment, heat (for instance low-grade, for instance at less than100°C) produced by a recovery process could be used in another VORP.

[0028] Some operations also produce or consume hydrocarbon solvents, which are purchased at a significant cost. Due to impurity or irregular timing, excess hydrocarbon solvent produced by the recovery operations could be used elsewhere, for instance as boiler fuel. Although this approach does not generate high utilization value for the solvent, it may be preferable to building solvent recovery units and associated storage facilities.

[0029] Resources targeted by SDRPs include bitumen deposits where thermal recovery operations are not feasible or preferred due to low bitumen saturation or thin resource thickness. It is expected that these relatively marginal resources may often be adjacent to thermal operations exploiting thicker, higher bitumen saturation resources, or adjacent to mining operations exploiting shallow resources. The relatively marginal resources may also be located deeper or shallower than the resource being exploited by the thermal process. In one embodiment, a SDRP is integrated with another VORP at the same or a nearby location, while accessing different subsurface resources. One SDRP may also be practiced nearby another SDRP; and to cite but one example, a CSDRP may be integrated with VAPEX.

[0030] Figure 2 is a flow chart outlining the integration of a SDRP with a VORP, according to a disclosed embodiment. As shown in Figure 2, an SDRP is operated (202), a VORP is operated (204), and the two are integrated (206) through at least one of: solvent, heat, a production stream, and a viscous oil reservoir.

[0031] Various embodiments of this integration will now be described. These embodiments are arranged in three categories. In the first category, a SDRP is integrated with a mining operation. In the second category, a SDRP is integrated with an *in situ* VORP. In the third category, a SDRP and *in situ* VORP are operated on a common reservoir.

[0032] 1: First category: SDRP integrated with a mining operation

[0033] 1-A: Solvent Sharing

[0034] In this embodiment, solvent is shared between a mining process and a SDRP. The mining process uses a solvent (for instance a light hydrocarbon such as propane to hexane to partially or fully de-asphalt bitumen, or naphtha for upgrading). A SDRP injects solvent and recovers solvent and viscous oil. These two processes can share a common solvent source and/or method of transportation, for instance a pipeline network. The processes can also share solvent storage. In this way, facilities are reduced. The solvent recovery unit of a mining process may produce a product stream that does not meet quality specification for the next stage of processing and is recycled through the facility during period of plant upsets. As an example, due to a lower than design temperature in the solvent recovery unit, higher molecular weight hydrocarbon liquids are now mixed with solvent and will foul the de-asphalting process, if recycled. While this product is detrimental to the mineable oil sands processing operation, it may actually be beneficial to an SDRP as the higher molecular weight hydrocarbon liquids may improve miscibility and solvent solubility with viscous oil. Therefore, this product can be injected into the underground formation targeted for the SDRP to improve recovery or extraction efficiency. The "off-specification" solvent stream can also be blended with source solvent to be injected into the SDRP targeted underground reservoir(s).

[0035] 1-B: Blending SDRP and Mining Production to Capture Product Value

[0036] The production stream from a SDRP using a light hydrocarbon solvent (for instance propane to pentane), may produce a light liquid phase at the early stage of production. This light stream is nearly de-asphalted with pentane-insoluble components removed and has a higher value than bitumen. This quality improvement value is lost if the product is mixed and sold with heavier components such as whole bitumen. Given that a mining process may produce partially or fully de-asphalted bitumen, in this embodiment, the light stream from the SDRP is combined and sold with the mining up-graded stream to take better advantage of its increased product value.

[0037] The mid- to late-stage production from a SDRP may produce a heavy phase that comprises a higher proportion of pentane-insoluble components than whole bitumen. This heavy stream provides a higher asphalt yield than bitumen and asphalt value peaks during high demand periods. This heavy stream can be combined with the bottom fraction from the de-asphalting facility in the operation to be processed or transported to a nearby facility to maximize asphalt production during peak demand season. In the low demand periods, the heavy phase can be blended with other streams to be sold as bitumen, sometimes further diluted with a diluent such as a gas condensate.

[0038] 1-C: Heat Sharing

[0039] The tailings stream from a froth separation unit in a mining operation may be about 90° C. In this embodiment, the waste heat from the tailings stream may be used in one of more of the following ways:

[0040] (a) to pre-heat a solvent injection stream (for instance up to 90°C) for SDRP injection

[0041] (b) to circulate down a SDRP well via a carrier fluid (for instance glycol, for instance in a slim tube) to heat (for instance to 55°C) and reduce the viscosity of the production stream from a SDRP to increase production rate.

[0042] (c) to heat a surface production system in a SDRP facility (for instance up to 55° C) for providing flow assurance; and

[0043] (d) to heat a SDRP production stream to vapourize and recover solvent (for instance at 50 to 90°C) above ground, for instance in a separator.

[0044] The waste heat may be captured using heat exchangers.

[0045] 1-D: Other Product Sharing Synergy

[0046] The miscibility of light hydrocarbon solvents with viscous oils can be altered by blending the solvent with higher molecular weight hydrocarbon liquids. De-asphalted or upgraded bitumen from a mining operation (including from a stand-alone upgrader) can be added to source solvent to be injected into SDRP wells to improve miscibility and increase bitumen recovery.

[0047] Mining processing byproduct gases such as CO_2, CH_4 and SO_2 can be added to SDRP solvent and injected to target wells to enhance bitumen and solvent recovery.

[0048] Mining processing byproduct gas can be used as a gas lift gas for SDRP wells.

[0049] Blending SDRP and mining bitumen streams can reduce demand for diluent for pipelining when de-asphalted bitumen is blended with heavy components of bitumen as a result of in situ separation of bitumen in SDRP.

[0050] 2: Second category: SDRP integrated with an *in situ* VORP

[0051] 2-A: Solvent and Product Sharing

[0052] In this embodiment, a common solvent source and transportation system (for instance a pipeline network) is used to meet *in situ* VORP and SDRP needs. For cyclic SDRP (CSDRP) methods, integrating with an *in situ* VORP operation provides more wells for injecting solvent and more wells as storage for recycling solvent, thus providing more flexibility for scheduling wells for injection and production, especially during the startup phases of both processes. Blending early SDRP production, i.e. the light phase, with an *in situ* VORP bitumen stream reduces the demand for diluent for pipelining.

[0053] 2-B: Heat Sharing

[0054] In this embodiment, waste heat from VORP facilities (for instance CSS facilities) such as boiler exhaust (for instance at 200°C to 300°C), a hot flow-back production stream (for instance at 220°C), or waste heat from glycol systems (for instance 80°C) is used through heat exchangers to:

[0055] (a) pre-heat a solvent injection stream (for instance up to 90°C) for SDRP injection;

[0056] (b) circulate down a SDRP well via a carrier fluid (for instance glycol, for instance in a slim tube) to heat (for instance to 55°C) and reduce the viscosity of the production stream from a SDRP to increase production rate;

[0057] (c) heat a surface production system in a SDRP facility (for instance up to 55° C) for providing flow assurance; and

[0058] (d) to heat a SDRP production stream to vapourize and recover solvent (for instance at 50 to 90°C) above ground, for instance in a separator. A heat exchange (for instance using counter-current flow) may be used. This offers beneficial cooling to the *in situ* VORP facilities.

[0059] 2-C: Greenhouse Gas (GHG) Capture

[0060] An *in situ* VORP may produce greenhouse gases. In this embodiment, greenhouse gases are removed and injected with solvent into SDRP wells. In this way, greenhouse gases may be sequestered and SDRP viscous oil and solvent recoveries may be improved. Integrating VORP and SDRP operations may lower the greenhouse gas intensity of the combined operations since SDRP may have a lower greenhouse gas intensity (for instance 10% of the greenhouse gas intensity as compared to a thermal *in situ* VORP).

[0061] 2-D: Gas Sharing

[0062] By integrating *in situ* VORP and SDRP operations, a single casing gas compression system can be used for both processes when their respective facilities are in close proximity (for instance up to 5 km) to each other. Non-recyclable combustible gases from an SDRP operation can be used to fuel VORP boilers. Non-condensable gases from an *in situ* VORP operation can be used to pressurize annulus gas or as lift gas in SDRP wells.

[0063] 3: Third category: SDRP and *in situ* VORP are operated on a common reservoir

[0064] Various SDRPs (for instance VAPEX) can be implemented as a follow-up process to another *in situ* VORP which may leave a sufficient residual hydrocarbon base to justify the follow-up SDRP. The remnant heat in the VORP reservoirs (for instance up to 120°C) may provide energy needed to generate vapour solvent for some of the SDRP follow-up operations.

[0065] Various VORP displacement methods, such as SAGD, SA-SAGD, or steam-flood, require that fluid communication be established between injection and producer wells before such operation can be sustained. Some SDRPs, such as CSDRPs, can be implemented first in viscous oil reservoirs until fluid communication is established between wells and then these wells may be converted to *in situ* VORP displacement operations. Some *in situ* VORPs, especially the ones that are gravity-stabilized, may have high oil recovery efficiency (for instance greater than 60% of original oil in place).

[0066] Various *in situ* VORPs (for instance steam flood) can be implemented as a follow-up process to a SDRP which may leave a sufficient residual hydrocarbon base remaining to justify the implementation of the follow-up operation. The remnant solvent in the SDRP reservoirs (for instance up to 10 volume percent of injected value) may provide the required mobility in the reservoir fluid to effectively carry out the *in situ* VORP operation without excessive bypassing of the viscous oil related to drive fluid fingering.

[0067] The at least two processes may be operated simultaneously, consecutively, with overlap, or as a hybrid process, and on the same or separate reservoirs.

[0068] CSDRP

[0069] In one embodiment, the CSDRP comprises: (a) injecting a volume of fluid comprising greater than 50 mass % of a solvent, wherein the solvent is a viscosity-reducing solvent, into an injection well completed in the reservoir; (b) halting injection into the injection well and subsequently producing at least a fraction of the injected fluid and the *in situ* viscous oil from the reservoir through a production well; (c) halting production through the production well; and (d) subsequently repeating the cycle of steps (a) to (c); wherein, in at least one subsequent cycle, an *in situ* volume of fluid injected in step (a) is equal to a net *in situ* volume of fluids produced from the production well in an immediately preceding cycle plus an additional *in situ* volume of the fluid. Immediately after halting injection into the injection well, at least 25 mass % of the injected solvent may be in a liquid state in the reservoir.

[0070] In the preceding description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the embodiments of the invention. However, it will be apparent to one skilled in the art that these specific details are not required in order to practice the invention.

[0071] The above-described embodiments of the invention are intended to be examples only. Alterations, modifications and variations can be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

WHAT IS CLAIMED IS:

1. A method of operating at least two different viscous oil recovery processes, the method comprising:

operating a solvent dominated recovery process (SDRP);

operating a viscous oil recovery process (VORP); and

integrating the SDRP and the VORP through at least one of: solvent, heat, a production stream, and a viscous oil reservoir.

2. The method of claim 1, wherein the VORP comprises extraction of mined oil sand.

3. The method of claim 2, wherein the extraction of the mined oil sand comprises aqueous-based extraction, and subsequent solvent use.

4. The method of claim 2, wherein the extraction of the mined oil sand comprises solvent-based extraction.

5. The method of any one of claims 2 to 4, wherein the integration comprises sharing a common solvent source, method of solvent transportation, or solvent storage, or more than one of the foregoing.

6. The method of any one of claims 2 to 4, comprising using solvent from the extraction of the mined oil sand in the SDRP for subsurface injection.

7. The method of claim 6, wherein the solvent from the extraction of the mined oil sand comprises off-specification solvent.

8. The method of any one of claims 2 to 4, wherein the integration comprises combining production streams of the SDRP and the VORP.

9. The method of claim 8, wherein the integration comprises combining a light liquid phase, having a lower proportion of pentane-insoluble components than bitumen, produced

from an early stage of the SDRP, with an upgraded bitumen stream from the extraction of the mined oil sand.

10. The method of claim 8, wherein the integration comprises combining a heavy liquid phase, having a higher proportion of pentane-insoluble components than bitumen, produced from a mid- to late-stage of the SDRP, with a bottom fraction produced by the extraction of the mined oil sand.

11. The method of claim 2 or 3, wherein the extraction of the mined oil sand generates heat, and wherein the integration comprises using the heat in the SDRP to heat:

(a) solvent prior to subsurface solvent injection in the SDRP;

(b) solvent during production in the SDRP to assist flow assurance;

(c) a SDRP production stream to vapourize and recover solvent above ground; or

(d) a carrier fluid for downhole circulation to reduce a SDRP production stream's viscosity, to increase a SDRP production rate.

12. The method of claim 11, wherein the heat generated from the extraction of the mined oil sand comprises waste heat recovered from a tailings stream from a froth separation unit of the extraction of the mined oil sand.

13. The method of claim 12, wherein the heat is removed from the tailings stream by a heat exchanger.

14. The method of any one of claims 2 to 4, wherein the integration comprises adding de-asphalted or upgraded bitumen from the extraction of the mined oil sand to solvent for subsurface injection in the SDRP, for improving miscibility and increasing viscous oil recovery.

15. The method of any one of claims 2 to 4, wherein the integration comprises adding a byproduct gas from the extraction of the mined oil sand, comprising CO_2, CH_4, or SO_2, or a combination thereof, to solvent for subsurface injection in one or more target wells in the SDRP, for enhancing viscous oil recovery, solvent recovery, or both.

16. The method of any one of claims 2 to 4, wherein the integration comprises using a byproduct gas from the extraction of the mined oil sand as a gas lift gas for in one or more SDRP well.

17. The method of any one of claims 2 to 4, wherein the integration comprises blending a viscous oil stream from the extraction of the mined oil sand with a heavier viscous oil stream from the SDRP, for reducing diluent demand in pipelining of the heavier viscous oil stream.

18. The method of claim 1, wherein the VORP is an *in situ* VORP.

19. The method of claim 18, wherein the integration comprises sharing a common solvent source, method of transportation, or storage, or more than one of the foregoing.

20. The method of claim 19, wherein:

the SDRP comprises a cyclic SDRP (CSDRP); and

the integration comprises blending an early stage, light CSDRP production stream with an *in situ* VORP production stream, for reducing diluent demand in pipelining the *in situ* VORP production stream.

21. The method of claim 18, wherein the *in situ* VORP generates heat, and wherein the integration comprises using the generated heat in the SDRP to heat:

(a) solvent prior to subsurface solvent injection in the SDRP;

(b) solvent during production in the SDRP to assist flow assurance;

(c) a SDRP production stream to vapourize and recover solvent above ground; or

(d) a carrier fluid for downhole circulation to reduce a SDRP production stream's viscosity, to increase a SDRP production rate.

22. The method of claim 21, wherein the heat generated in the *in situ* VORP comprises heat from boiler exhaust, a hot flow-back production stream, or a combination thereof.

23. The method of claim 18, wherein the integration comprises injecting at least one greenhouse gas from the *in situ* VORP into SDRP wells.

24. The method of claim 23, wherein the greenhouse gas comprises CO_2.

25. The method of claim 1, wherein:

the VORP is an *in situ* VORP; and

the integration comprises operating the SDRP and then operating the *in situ* VORP in the same underground reservoir.

26. The method of claim 25, wherein the SDRP is VAPEX.

27. The method of claim 25 or 26, wherein the *in situ* VORP is SAGD, SA-SAGD, or steam flooding.

28. The method of claim 1, wherein:

the VORP is an *in situ* VORP; and

the integration comprises operating the *in situ* VORP and then operating the SDRP in the same reservoir.

29. The method of claim 28, wherein the *in situ* VORP is steam flooding.

30. The method of any one of claims 18 to 24, wherein the *in situ* VORP is CSS (Cyclic Steam Stimulation), SAGD (Steam Assisted Gravity Drainage), SA-SAGD (Solvent Assisted-Steam Assisted Gravity Drainage), VAPEX (Vapor Extraction), LASER (Liquid Addition to Steam for Enhancing Recovery), SAVEX (Combined Steam and Vapor Extraction Process), CSD (Constant Steam Drainage), steam drive, solvent flood, FIRE (Fluidized *In Situ* Reservoir Extraction), or water flooding.

31. The method of any one of claims 1 to 24, wherein the SDRP is VAPEX.

32. The method of any one of claims 1 to 24, wherein the SDRP is a cyclic SDRP (CSDRP).

33. The method of any one of claims 1 to 24, wherein the SDRP comprises:

(a) injecting a volume of fluid comprising greater than 50 mass % of a solvent, wherein the solvent is a viscosity-reducing solvent, into an injection well completed in the reservoir;

(b) halting injection into the injection well and subsequently producing at least a fraction of the injected fluid and the *in situ* viscous oil from the reservoir through a production well;

(c) halting production through the production well; and

(d) subsequently repeating the cycle of steps (a) to (c);

wherein, in at least one subsequent cycle, an *in situ* volume of fluid injected in step (a) is equal to a net *in situ* volume of fluids produced from the production well in an immediately preceding cycle plus an additional *in situ* volume of the fluid.

34. The method of claim 33, wherein immediately after halting injection into the injection well, at least 25 mass % of the injected solvent is in a liquid state in the reservoir.

35. The method of claim 33 or 34, wherein the injection well and the production well utilize a common wellbore.

36. The method of any one of claims 33 to 35, wherein the viscous oil has an *in situ* viscosity of at least 10 cP at initial reservoir conditions.

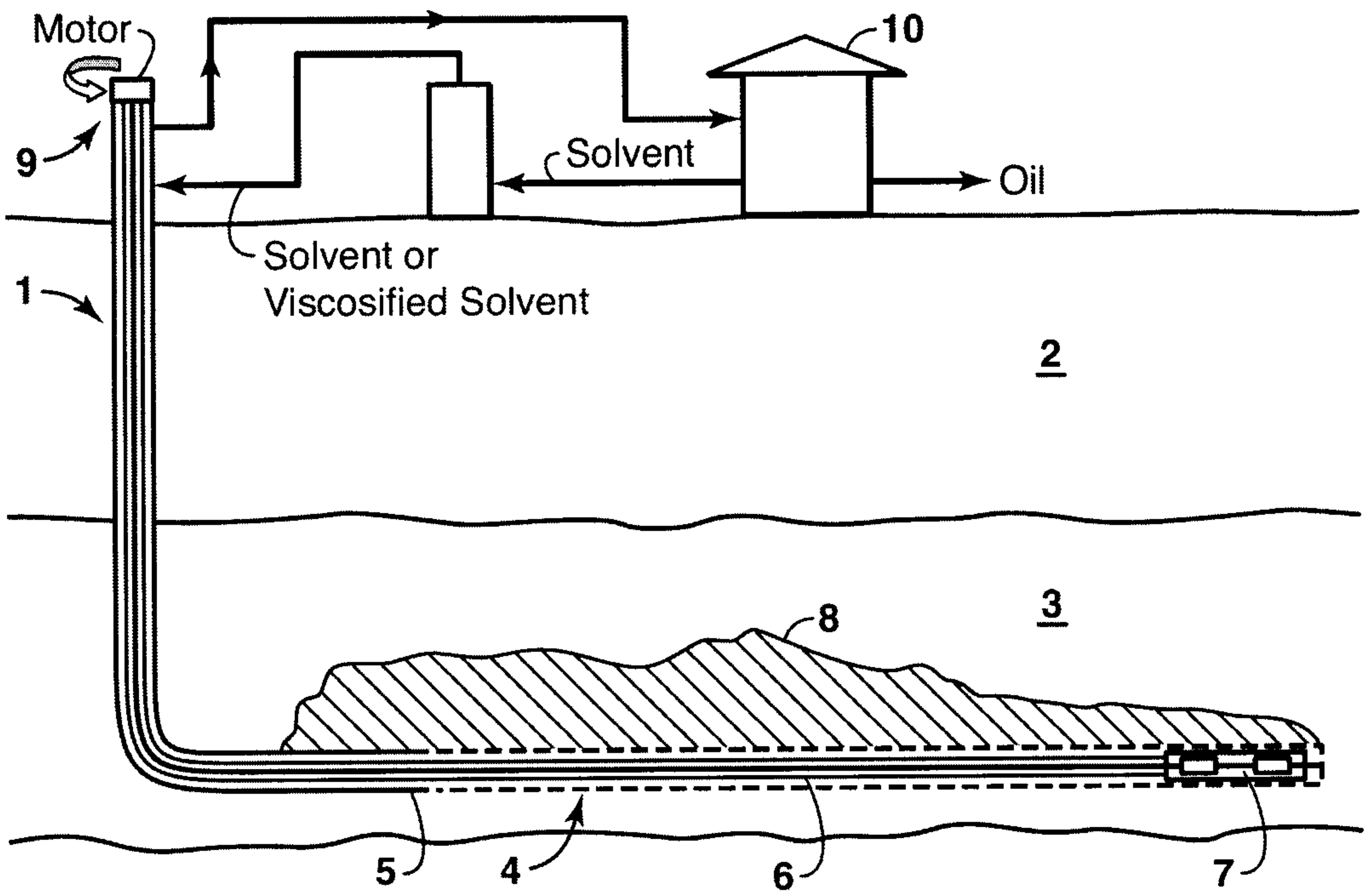


FIG. 1
(Prior Art)

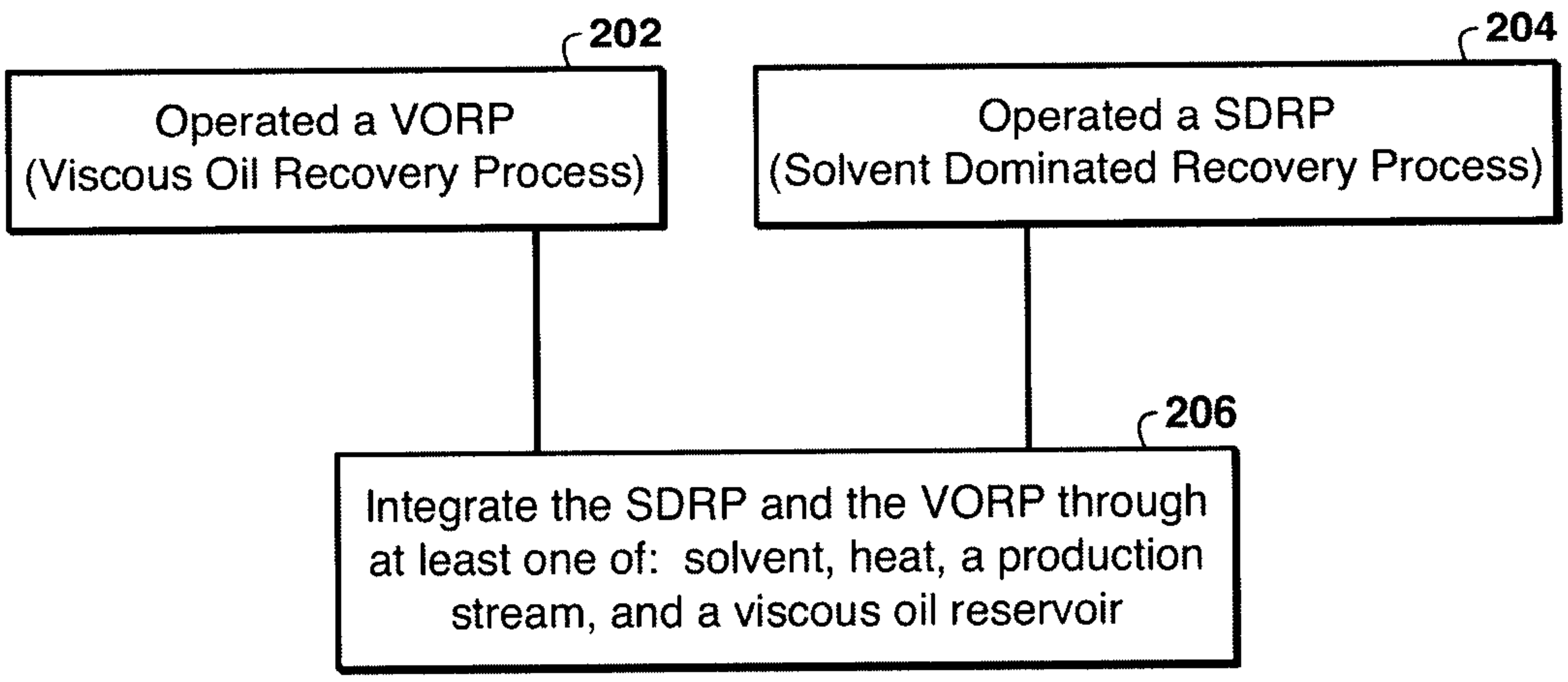
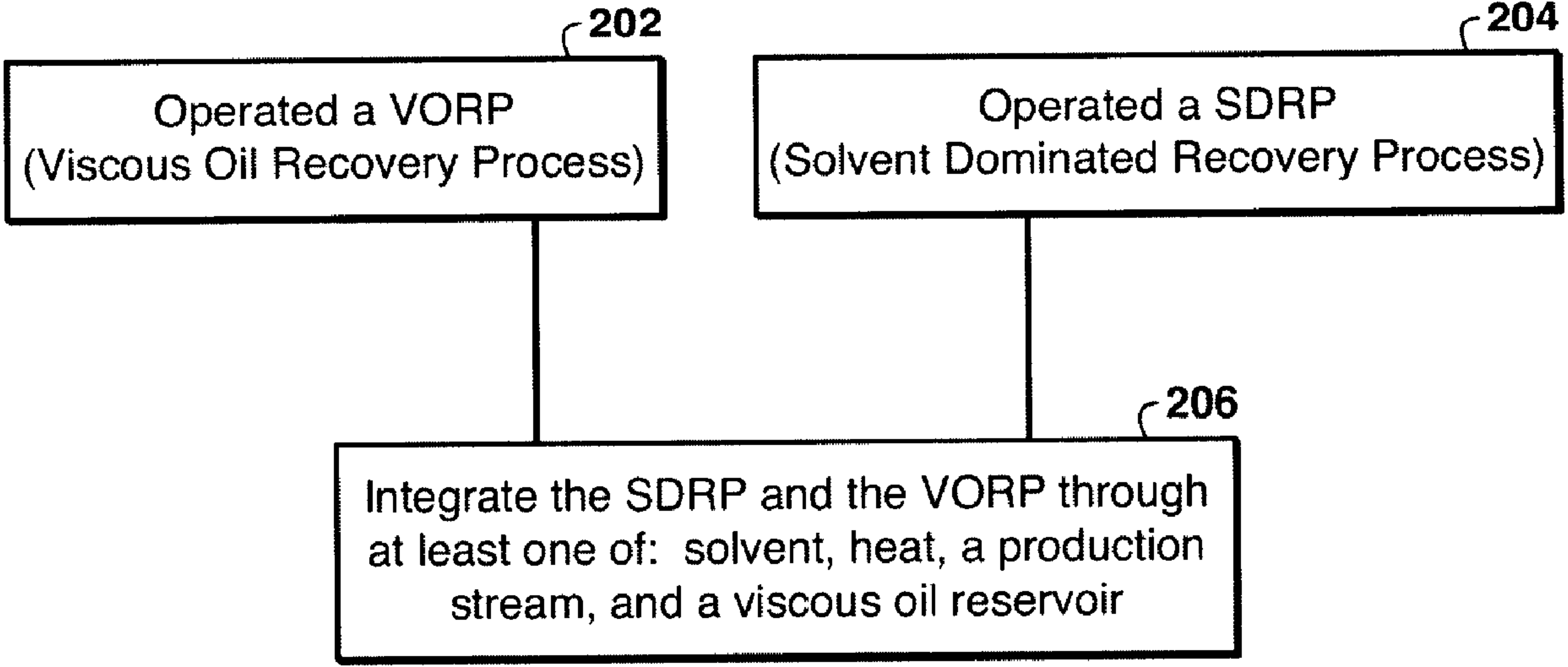


FIG. 2


202
Operated a VORP
(Viscous Oil Recovery Process)
204
Operated a SDRP
(Solvent Dominated Recovery Process)
206
Integrate the SDRP and the VORP through at least one of: solvent, heat, a production stream, and a viscous oil reservoir