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⑤④ **Recovery and reforming of ultra heavy tars and oil deposits.**

⑤⑦ A process is provided for the recovery from petroleum-bearing formations of ultra-heavy crudes and tars. A 'daisy' well is employed with a main central bore surrounded by an array of slant bores. Hydrogen donor solvent is injected under pressure into the formation via the central bore and high temperature flue gases are injected at higher pressure via the slant bores. Dissolved and liquefied hydrocarbons are recovered together with solvent by gas lift in the central bore. The recovered hydrocarbons are reformed by a thermochemical reforming plant adjacent the well-head to obtain a pipe-line quality product. The plant includes a high temperature high pressure furnace from the exhaust of which the hot flue gases are obtained, and output fractionation stages from which the solvent is recovered.

RECOVERY AND REFORMING OF
ULTRA HEAVY TARS AND OIL DEPOSITS

This invention relates to the recovery and conversion by reforming of ultra heavy tars and oils from both shallow and deep deposits.

With the traditional method of extraction and
5 recovery of ultra heavy tar, only deposits accessible to open-cast mining could be mined conventionally, the tar being heat-extracted in retorts after having been excavated from the mine pit. None of the existing methods can perform any conversion (reforming) of the oil at the
10 mining site to allow the pumping of an oil product into a transport pipeline. Furthermore, none of the existing methods of thermal or chemical recovery can liquefy and extract any substantial amount of ultra heavy hydrocarbons from the deposit, without violating the economic basis of
15 the mining operation.

A number of attempts have been made to achieve so called viscosity reduction in order to increase the mobility of the hydrocarbons in the formation, thereby enabling them to be withdrawn by conventional techniques, such as natural
20 flow, pumping, etc. The most popular method has been to reduce the viscosity of the hydrocarbons by elevating the temperature, in consequence of introducing thermal energy by a wide variety of means, such as hot water, in situ combustion, steam, heated natural and combustion gases and
25 chemicals convertible into high pressure hot gases. Some

of those techniques have received limited application in the recovery of medium heavy oil, API gravity in a range between 10° - 22°, with viscosity not much greater than 200 cp (both at 60°F) (16°C) and for a deposit with a
5 medium thickness of 50 - 100 feet (15 - 30 metres).

The so-called medium-heavy oils just referred to are, by their nature, mobile to a degree in the deposit, but their velocity of gravitational mobility is very low and can be increased by decreasing their viscosity.
10 Two basic thermal techniques of recovery are known for these medium-heavy-oils.

One technique is usually referred to as "steam-drive", wherein steam is continuously injected into a formation by means of an injection well. The injected steam heats
15 the formation and medium-viscous hydrocarbons and drives the heated hydrocarbons toward one or more adjacent vertical production wells which are employed to withdraw them to the surface. There are the strict conditions limiting this kind of steam driving process, such as:

20 a) the formation must not be plugged by the gradually cooling products, which means that the natural non-heated oil ought to be light and mobile enough by itself to avoid its solidification when it cools.

b) the permeability of the formation should be
25 high enough to allow penetration of the steam, despite the fact that hydrocarbon material is consolidated in the pores.

c) the pressure of the steam and its temperature should be sufficiently high to allow deep penetration into the formation.

Even when these conditions are fulfilled, only a
5 small portion of the medium-heavy-crude, and rather its light fraction only, can be mobilized and extracted by the steam-drive system, and only from the very upper part of the formation, where the steam has a natural tendency to sweep around the injection well. The lower part of the
10 deposit in general remains unheated and worse, becomes impregnated with the previously heated heavier fractions of the oil from the upper part of the formation that have descended and cooled in the lower part of the formation. As a result, the lower part of the formation is converted
15 into strata that are nonpermeable to any heat carriers, and remains lost as regards further recovery processes.

An alternative to "steam-drive" is "hot water drive" which, in one of the most advanced processes (U.S. Patent 4,305,463) employs a flushing medium injected
20 in a series of pressure pulses to force the heated fluids through the pores by hydraulic ramming. However, despite dramatic improvements in the effect of "driving" the hydrocarbons through the formation pores, the method still has application to light and medium heavy oils only, and
25 cannot be used for ultra heavy tars and asphalts.

In the second basic technique, commonly referred to as single well injection or "huff and puff", steam, heated gases, combustion gases, or a combination of them is injected into the formation through a single injection well in a batch quantity for a selected period (huff phase). The formation is allowed to "soak", during which time the heat permeates, heating a larger volume of the hydrocarbon reservoir, and the heated mobile hydrocarbons are supposed then to be withdrawable from the formation through the same well during an extraction period (puff phase).

The "huff and puff" technique has arisen due to the known inefficiency of the steam and hot water driving methods, in an attempt to deal with heavier oils and thicker deposits. However, this process basically contradicts the logic of the use of driving forces in the formation, as commonly applied in the production of liquids from boreholes; it delivers small quantities of melted, heated product, and only in the case of a formation thick enough to allow some product to flow into the injection well from the inverted cone region of the formation that is heated by the injection and soak. The major portion of the heated, melted hydrocarbon is repelled in the "huff phase" into peripheral parts of the well region where it impregnates, solidifies in and plugs the pores of the formation.

There are, of course, many modified versions of these two basic techniques known in the art. Many such

processes involve the injection of chemicals along with,
or as an alternative to, steam into the formation; for
example, see U.S. Patents Nos. 3,292,702; 3,409,083;
3,500,931; 3,782,470; 3,948,323; 4,305,463; which
5 disclose modified versions of the above techniques.

There are processes which include so-called
"enhanced recovery" techniques employing different
chemicals and agents, all of them aiming to achieve better
mobility of the oil by gravitational and/or pressure-
10 forced flow of liquids. The majority of these techniques
are orientated towards decreasing surface tension between
oil and water phases, and/or decreasing the oil viscosity
in the formation. Some of these known techniques have
limited use in the recovery of medium-heavy-crude under
15 certain conditions. However, despite all these efforts
the majority of the oil-bearing formations all around the
world are known to contain enormous reserves of heavy
and ultra-heavy hydrocarbons from which the crude cannot
technically and economically be recovered in large
20 quantities by the employment of any known process. None
of the known processes is able to provide any improvement
in the mobility of ultra-heavy crude or any reforming
and conversion of ultra-heavy crude into a lighter product
i.e. of pipeline quality - at the well site.

25 Accordingly, it is an object of the present
invention to achieve a process for efficient recovery of

ultra-heavy and heavy hydrocarbons and tars, particularly crudes having API gravity below 15° (at 60° F) (16° C), from consolidated or non-consolidated formations having low to very high relative permeability to oil, gas and water.

5 According to the present invention, there is provided a process for the recovery of heavy and ultra-heavy hydrocarbons from formations containing petroleum deposits, comprising:

 injecting into the formation either concurrently
10 or cyclically:-

 a) hot flue gases obtained from the combustion of fuel at high temperature and pressure; and

 b) a hydrogen donor solvent liquid;

 and raising the hydrocarbons thereby mobilised and
15 liquefied by gas lift.

 Preferably, the recovery is performed in a 'daisy' well having a main central bore and a plurality of slant bores with their lower terminations lying in an array surrounding the central bore. Preferably also, the flue
20 gases are injected at high pressure down the slant bores, the solvent is injected at a lower pressure down the main central bore, and the gas lift is generated in a casing of the main central bore. The flue gases may be obtained from the furnace of a thermochemical reforming plant employed
25 to reform the recovered hydrocarbons into a lighter product adjacent the well head. The solvent may be a highly hydrogenated naphthenic solvent obtained as a

fraction from the product output of the thermochemical reforming plant.

The invention further provides a well for the recovery of heavy and ultra-heavy hydrocarbons from
5 formations containing petroleum deposits, comprising a main central bore and a plurality of slant bores terminating at their lower ends in an array around the central bore, the main central bore containing at least a passage for delivering solvent downward for injection into the formation
10 and a passage in which extracted hydrocarbons are raised by gas lift, and the slant bores each containing at least a passage delivering hot flue gases downward for injection into the formation.

In the preferred form, the main bore is formed at
15 an intermediate level with a chamber having a platform across it, the slant bores commence at and extend downward from the platform, and above the intermediate chamber the main bore includes also a passage delivering hot flue gases downward to the slant bores.

20 The well may be operated in conjunction with a thermochemical reforming plant adjacent the well head which reforms the recovered hydrocarbons to produce a pipe-line quality product, said plant including a furnace supplying the hot flue gases for the well, and means for fractioning
25 the plant output to obtain the solvent.

One example of a process, well system and plant for performing the invention will now be described with reference to the accompanying drawing, which is a schematic of the well and the plant.

5 In the example shown, the feed stock for the plant is obtained from a 'daisy' well 10 with a central solvent injection and production bore 12 surrounded by six slanting gas injection bores 13. In the case of a thick deposit, one such 'daisy' well can recover as much as 80% of the
10 total accumulation of hydrocarbons over an area of approximately 1 to 1.2 acres (0.4 to 0.49 ha).

The feed stock from the annular casing 14 of the production bore 12, which will typically be an emulsion of crude, solvent, water and gas, enters a main separator 11
15 at elevated temperature and pressure, for example, 450°F (232°C) and 460 PSIG ($3151 \times 10^3 \text{ N/m}^2$).

The main separator 11, which has internal vertical apertured baffles 31, separates the diluted crude from the water and sand. Vaporized hydrocarbons are condensed in a
20 condenser 15 which is an inlet stage of gas scrubber 16 from which carbon dioxide and nitrogen are vented. The condenser has a coil which is cooled by raw water pumped from a well or reservoir by a pump 17. The water, after passing through the condenser 15, is introduced into the cooling coil
25 system 18 of the desander-desalter separator 19 from where

it passes into a furnace water jacket 20 of a high pressure thermochemical reformer 21 and thence as steam into the coil of a steam superheater 22 at about 450°F (232°C). Between the water jacket 20 and the steam superheater 22, a by-pass stream is withdrawn at a process control valve 24 and injected continuously, or cyclically, into thermochemical reforming coils 23 through process control valves 25, 26. Superheated steam from the steam superheater 22 is injected into a sand jet-washing system 27 in the main separator 11 where it condenses, and whence it carries entrained sand into the desanding-desalting separator 19. The water is cooled somewhat in the separator 19, and the settling sand is discharged, at 28, by a screw feeder 32.

Separated, largely de-emulsified crude in solvent, under the internal pressure of the main separator 11, is introduced at a temperature of about 420°F (216°C) into a quencher-hydrogenator 29 in which it is reacted with superheated thermally cracked hydrocarbon, and hydrogen generated principally in the coil system 23 of the thermochemical reformer 21 from which it enters the quencher-hydrogenator usually at a temperature not less than 1300°F (704°C). Quenched and hydrogenated crude under the internal pressure of the quencher-hydrogenator 29 leaves at about 850°F (454°C) and is introduced into a first stage fractionator 30 at an inlet temperature of, for example,

800°F (427°C). The heavy liquid fraction separated in the fractionator 30 is recycled by a pump 33 to the process control valves 26, 25 and through the coils 23 of the thermochemical reformer into the quencher-hydrogenator 29.

5 The light vapour fraction from the fractionator 30 is condensed in an air-cooled condenser 34 and pumped by a pump 36 at about 550°F (288°C) into a second stage fractionator 35, from where the liquid fraction, which is a heavy distillate, is pumped off by a pump 37 and recycled,
10 via a process control valve 44 and the valves 25, 26, through the coils 23 in the thermochemical reformer to the quencher-hydrogenator 29. The lighter vapour fraction from the fractionator 35 is condensed in an air-cooled condenser 38 and pumped by a pump 39 at about 300°F (149°C) to a third
15 stage fractionator 40. The liquid fraction from the third stage fractionator is a final pipeline quality commercial product, up to 40° API gravity, and is pumped away by a pump 41 via process control valves 42, 43 to a final reformed product pipeline 45.

20 The vapour fraction from the fractionator 40 is condensed in an air-cooled condenser 46 and injected by a pump 47 via a process control valve 48, at a temperature of about 200°F (93°C), down the central pipe 49 of the production bore 12 to act as hydrogen donor solvent to
25 dissolve and partially reform the in situ crude by non-catalytic hydrogenation in the presence of flue gas components and in reaction with them.

The hydrogen donor solvent is a highly hydrogenated naphthene fraction having a boiling range usually between 150° and 250°F (66° - 121°C). The amount of solvent needed for crude extraction is usually approximately 25% by weight of the recovered crude. Further portions of it can be blended with the final product or employed to dilute the hydrocarbon liquids returning to the thermochemical reformer from the first and second stage fractionators.

The high pressure, high temperature thermochemical reforming reactor 21 produces high temperature combustion gases and performs the following functions:

- i) thermal cracking,
- ii) thermochemical reforming,
- iii) hydrogen generation
- iv) coke deposition and decoking.

The superheated flue gases leaving the thermochemical reformer at 800 - 1000°F (427 - 538°C) and 800 - 1000 PSI ($5480 \times 10^3 - 6850 \times 10^3 \text{ N/m}^2$) are fed to the outer casing of the production well and thence into the gas injection bores 13 to react with the hydrogen donor solvent and the in situ crude. Hot water at about 200°F (93°C) is also supplied into the outer casing 50 from the desander-desalter 19 by a pump 51.

The thermochemical reforming reactor 21 has a water-jacketed high pressure refractory furnace 52 with a burner system fed by high pressure fuel pumps 53 and a compressor 54 into which the gaseous fraction from the condenser 46

is introduced for use as fuel. The main fuel for the furnace may be gas or liquid hydrocarbon or pulverised coal, but is preferably obtained from the crude being treated in the process. It is injected at high pressure,
5 together with compressed air which can, if desired, be oxygen enriched. The furnace 52 opens into the section of the reactor containing the reforming coils 23, which is followed by the section containing the steam super-heater 22. The system is designed to restrict the decompression and
10 flow of the combustion gases from the furnace so that a high intensity condensed flame is obtained and a very high combustion gas temperature is reached, not less than 3000°F (1649°C).

The coil system 23 of the thermochemical
15 reformer has dual interconnected passageways 55, 56 controlled by the process control valves 24, 25, 26. While one pass is charged with heavy hydrocarbons from the fractionators 30, 35 for thermal cracking and coke deposition, the other pass is fed with steam from the by-
20 pass valve 24 to provide a water gas reaction with the deposited coke and generate hydrogen. The hydrogen mixes with the crude and partially refined hydrocarbons and provides the hydrogenation reaction in the quencher-hydrogenator 29. The process control valves 24, 25, 26
25 are operated to switch the flows of hydrocarbons and steam

cyclically between the coil passages 55 and 56 so as to maintain the water gas reaction, but the hydrogen flow into the quencher hydrogenator, and hence the hydrogenation reaction, is substantially continuous. Additional hydrogen
5 is generated in the quencher hydrogenator by reaction of the flue gases with residual steam from the coils 23.

The function of the water jacket 20 around the furnace 52 is to raise the water temperature to generate steam for the water gas reaction with the deposited coke.
10 Provision for a large amount of coke deposition is made by enlargement of the diameter of the tubing of each coil to form a coke deposition chamber in which the hydrocarbon flow velocity is decreased, these chambers being situated toward the furnace end of the reforming section where
15 combustion is still continuing around the coils 23 so that the coke deposition chambers are exposed to a very high heat intensity. With deposition of a sufficient amount of coke, there is a lowering of the hydrocarbon viscosity, and that means a better hydrocarbon quality is obtained
20 after just the first stage of reforming. The coke deposition chambers are constructed from high quality metal alloy resistant to high temperature and high external pressure.

The process valves 24, 25, 26 have controllers
25 designed to provide manual or automatic control of the entire water gas reaction in the thermochemical reformer.

As regards the 'daisy' well itself, the slant bores 13 are fitted with internal tubes 60, of smaller diameter than the bore casings 62, to convey the hot flue gases from the thermochemical reformer to discharge filters 61 at the bottom ends of the slant wells. Seals 59 at the lower ends of the tubes 60 prevent passage of the gases up the bores outside the tubes. The slant wells 13 can, if desired, be drilled from the surface at points close around the main shaft 12, but in the example shown they are drilled from inside the main shaft. To this end, the main shaft 12 has a larger diameter upper section 12A and a smaller diameter lower section 12B, the bottom end portion of the larger diameter upper section being constituted as a drilling gas-distributing and product-collecting chamber 63, and the slant wells commence from a platform 64 across the chamber 63.

Above the chamber 63, the upper section 12A of the main shaft includes, concentrically arranged and in increasing order of diameter, the central injection pipe 49 for hydrogen donor solvent, the intermediate casing 14 for product upflow, the outer casing 50 for the hot flue gases, and finally the outer bore 65 of the shaft. The lower end of the casing 50 terminates at the roof of the chamber 63 so that the hot flue gases are discharged into the portion of the chamber above the platform 64 thereby

to enter the tubes 60. At the upper ends of the slant wells 13, the casings 62 are sealed to the platform 64 and also the gaps between the casings 62 and the tubes 60 are sealed by means of sealing cones 66, but the upper
5 ends of the tubes 60 are open for entry of the hot flue gases. Above the chamber 63, the annular space within the main shaft bore 65 and the casing 50 is filled with thermally-insulating concrete 67. This concrete can be placed by means of a tube lowered initially to the deepest
10 part of the void annular space to be filled and gradually retracted upwards as concrete is injected, keeping the lower end of the tube always beneath the level of the liquid concrete. One or more sliding thermal expansion joints may be provided in the metal casings of the main
15 shaft.

Below the platform 64 in the chamber 63, the lower section 12B of the main shaft includes, concentrically arranged and in increasing order of diameter, the central solvent injection pipe 49, the intermediate casing 14 for
20 product upflow, and a outer casing 68 with a multiplicity of openings 69 fitted with filters for admitting liquid hydrocarbon product into the annular space between the casings 68 and 14. At the upper end of the casing 68 there are openings 69 lying within and communicating with the
25 portion of the chamber 63 below the platform 64. The casings 62 of the slant wells 13 are likewise provided

with openings 70 equipped with filters for the entry of hydrocarbon product into the annular spaces between the casings 62 and the tubes 60, and at the upper ends of the slant wells there are also openings 70 lying within and communicating with the portion of the chamber 63 below the platform 64. Therefore, the hydrocarbon product is able to pass from the casings 22 into the casing 68 by way of the lower portion of the chamber 63.

The casings 50 and 68 of the upper and lower sections of the main shaft are sturdily united by the chamber 63 to create an integral robust main shaft casing very resistant to destruction by subsidence of the oil-bearing formation or the overburden. The central injection pipe 49 opens into the lower end of the casing 68 which is formed as a filter outlet 71 into the oil-bearing formation. Seals 72 and 73 prevent the injected solvent from rising around the pipe 49 inside the casings 14 and 68. The lower section of the main shaft can also be provided with small lateral tubes for discharging solvent at different levels in the formation.

The upper end of the main shaft is equipped at the surface with a head-tree incorporating control valves for all the downgoing and upcoming fluids and control mechanism for a gas lift pump. To augment gas lift, the downflow of flue gases, or a portion of it, can be switched from the casing 50 into the casing 14 which latter constitutes the gas lift pump tube. Hydrocarbon product and

gases from the formation enter the pump tube 14 from the casing 68 through apertures 74, and the regulated entry of further gases into the pump tube lowers the gravity of the product liquid and creates a lifting effect

5 according to the well known air/gas lift principle. The valve of the gas lift pump may be simply a vertically sliding tube for selectively opening and closing gas ports that admit into the pump tube 14 flue gas at comparatively low pressure from the gas distribution chamber 63, or gas
10 at higher pressure from the casing 50. If desired, the flue gases entering the pump tube 14 may be passed in heat exchange with the collected hydrocarbon product that is about to be extracted from the well by means of the gas lift.

15 In operation, hot flue gases are injected under pressure into the formation at the lower ends of the slant wells thereby creating a dynamic heated zone at elevated pressure surrounding the central main shaft in very roughly hemispherical form as indicated by the arrows 75.
20 Hydrogen donor solvent is simultaneously injected at a controlled pressure lower than the flue gas pressure at the bottom of the main shaft. As a consequence of the injected flue gas pressure being higher than the pressure of the injected solvent, a dynamic barrier is created
25 against the outward flow and loss of solvent into the

surroundings. The heavy and ultra-heavy hydrocarbons in the formation are partially upgraded and converted into lighter crude in situ by the action of the hydrogen donor solvent at high temperature in the presence of components
5 of the flue gases. In general, the hydrogen donor solvent will be a naphthenic material.

The hydrocarbons are thus rendered mobile by the combined actions of dissolution, heat and partial reforming and are impelled toward the central main shaft.
10 A continuous inward flow of hydrocarbon liquids is produced by the displacement actions of the solvent and flue gases and by the fact that the pressure in the vicinity of the main shaft casing is reduced by the gas lift pumping effect in the main shaft, all fluids therefore tending to
15 migrate from the higher pressure injection zones to the region around the main shaft casing. The gas lift pumping is generated by flue gases flowing from the formation together with the liquids into the casings 68 and 14 of the main shaft, augmented if desired by direct
20 introduction of flue gases into the main shaft gas lift from the chamber 63 and/or the casing 50.

The locally produced fuel burned in the thermo-chemical reformer will usually be highly contaminated with sulphur, possibly as much as 5-7% by weight. The flue
25 gases injected into the formation will therefore contain,

as major contaminants, SO_2 , NO_x and CO , and the formation rock or sand will act as a decontaminating system to strip these from the flue gases. The remaining components, primarily CO_2 and N_2 act as agents in promoting the mobility
5 of the hydrocarbons in the formation already liquefied by the injected solvent. Any water in the formation will be converted in situ into steam by the high temperature flue gases and will augment their action. If desired, further steam can be produced by pumping or injecting waste
10 water from the thermochemical reforming plant into the main shaft casing where it will be gasified by the high temperature flue gases on their way down the shaft.

If desired, a cyclical, instead of continuous, mode of operation can be employed. Thus, in one phase the
15 solvent can be injected not only at the bottom of the main shaft but also at the bottoms of the slant wells and into the casings 14, 68 of the main shaft, so that it emerges into the formation through the intake filters as well, after which in a second phase flue gases, and steam generated in
20 the main casing, can be injected to sweep the liquefied hydrocarbons toward and into the lift pump casing and generate the gas lift.

The whole process of extraction of the heavy hydrocarbons, with partial reforming, followed by production
25 of a pipe-line quality product adjacent the well head in the thermochemical reforming plant, is entirely self-contained and has an advantageous heat balance, losses of

both heat and solvent being confined to a minimum. The energy consumption for producing a valuable saleable product from previously irrecoverable heavy hydrocarbons is therefore comparatively low, with no requirement for
5 transport of fuel or other consumable materials to the site. Furthermore, although the locally-produced fuel used is heavily contaminated with sulphur, cleaning of the flue gases is largely inherently achieved within the process itself before any residual gases are discharged to
10 atmosphere, which is a major factor in pollution control.

The hydrogen donor solvent is largely recovered with the hydrocarbon product from the well and is generated in the thermochemical reforming plant for reuse.

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CLAIMS:

1. A process for the recovery of heavy and ultra-heavy hydrocarbons from formations containing petroleum deposits, comprising:

injecting into the formation either concurrently
5 or cyclically:-

a) hot flue gases obtained from the combustion of fuel at high temperature and pressure; and

b) a hydrogen donor solvent liquid;

and raising the hydrocarbons thereby mobilised
10 and liquefied by gas lift.

2. A process according to Claim 1, wherein the recovery is performed in a 'daisy' well having a main central bore and a plurality of slant bores with their lower terminations lying in an array surrounding the
15 central bore.

3 A process according to Claim 2, wherein the flue gases are injected at high pressure down the slant bores, the solvent is injected at a lower pressure down the main central bore, and the gas lift is generated in a
20 casing of the main central bore.

4. A process according to Claim 2, wherein in a first phase solvent is injected down all bores, and in a second phase flue gases are injected down all bores and the gas lift is generated in a casing of the main central bore.

25 5. A process according to any one of the preceding

claims, wherein water is injected together with the hot flue gases to generate steam.

6. A process according to any one of the preceding claims, wherein the hot flue gases are obtained from the furnace of a thermochemical reforming plant employed to reform the recovered hydrocarbons into a lighter product adjacent the well head.

7. A process according to Claim 6, wherein the solvent is a highly hydrogenated naphthenic solvent obtained as a fraction from the product output of the thermochemical reforming plant.

8. A process according to Claim 6, or Claim 7, wherein the combustion conditions in the furnace of the thermochemical reforming plant reach a temperature of 800-1000°F (427-538°C) and a pressure of 800-1000 psi ($5480 \times 10^3 - 6850 \times 10^3 \text{ N/m}^2$).

9. A well for the recovery of heavy and ultra-heavy hydrocarbons from formations containing petroleum deposits, comprising a main central bore and a plurality of slant bores terminating at their lower ends in an array around the central bore, the main central bore containing at least a passage for delivering solvent downward for injection into the formation and a passage in which extracted hydrocarbons are raised by gas lift, and the slant bores each containing at least a passage delivering hot flue gases downward for injection into the

formation.

10. A well according to Claim 9, wherein the main bore is formed at an intermediate level with a chamber having a platform across it, the slant bores commence at
5 and extend downward from the platform, and above the intermediate chamber the main bore includes also a passage delivering hot flue gases downward to the slant bores.

11. A well according to Claim 10, wherein below the
10 platform the main bore has an outer casing with openings for the entry of liquid hydrocarbons and gas to the gas lift passage.

12. A well according to Claim 11, wherein the slant bores also have outer casings with openings for the entry
15 of liquid hydrocarbons and gas, said casings communicating with the gas lift passage of the main bore.

13. A well according to Claim 10 or Claim 11 or Claim 12, wherein the main bore above the intermediate chamber comprises, concentrically arranged, an inner pipe, an
20 intermediate casing and an outer casing surrounded by thermally-insulating concrete, the annular passage between the intermediate and outer casings communicating with the upper part of said chamber.

14. A well according to Claim 13, wherein each slant
25 bore comprises an inner tube and a concentric apertured

outer casing, the inner tube communicating with the upper part of said chamber.

15. A well according to any one of Claims 10 to 14, wherein the main bore below the platform in the intermediate
5 chamber comprises, concentrically arranged, an inner pipe, an apertured intermediate casing and an apertured outer casing.

16. A well according to any one of Claims 9 to 15, further comprising valve means for selectively admitting
10 hot flue gases to the gas lift passage of the main bore.

17. A well according to any one of claims 9 to 16, in combination with a thermochemical reforming plant adjacent the well head which reforms the recovered hydrocarbons to produce a pipe-line quality product, said plant including
15 a furnace supplying the hot flue gases for the well, and means for fractionating the plant output to obtain the solvent.

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