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HYDROCARBON RECOVERY BY THERMAL DRIVE

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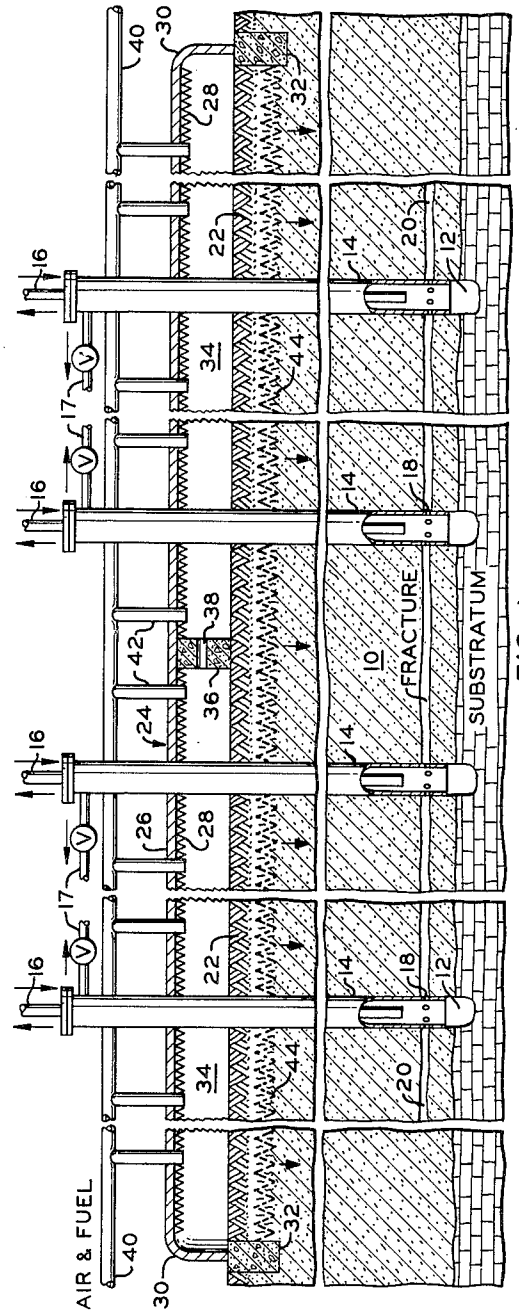

FIG. 1

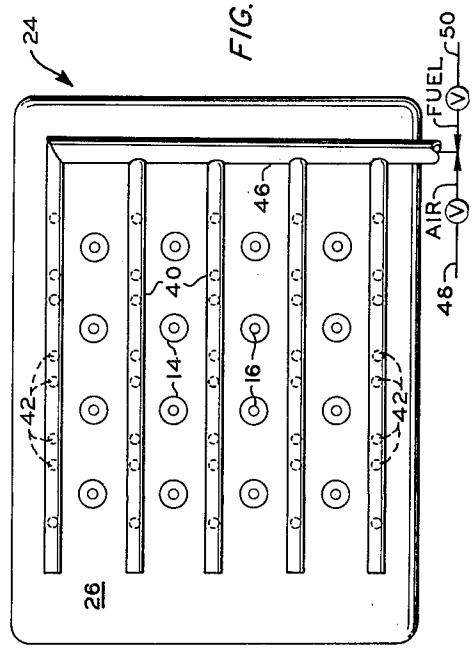

FIG. 2

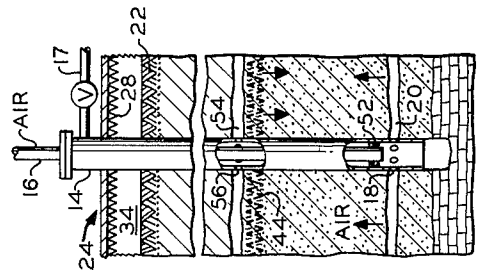

FIG. 3

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HYDROCARBON RECOVERY BY THERMAL DRIVE

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This invention relates to a process and apparatus for recovery of hydrocarbons from a carbonaceous stratum adjacent the ground surface by thermal drive to one or more boreholes therein.

In situ combustion in the recovery of hydrocarbons from underground strata containing carbonaceous material is becoming more prevalent in the petroleum industry. In this technique of production, combustion is initiated in the carbonaceous stratum and the resulting combustion zone is caused to move through the stratum by either inverse or direct air drive whereby the heat of combustion of a substantial proportion of the hydrocarbon in the stratum drives out and usually upgrades a substantial proportion of the unburned hydrocarbon material.

The ignition of carbonaceous material in a stratum around a borehole therein followed by injection of air through the ignition borehole in the stratum is a direct air drive process for effecting in situ combustion and recovery of hydrocarbons from the stratum. In this type of operation the stratum frequently plugs in front of the combustion zone because a heavy viscous liquid bank of hydrocarbon collects in the stratum in advance of the combustion zone which prevents movement of air to the combustion process. To overcome this difficulty and to permit the continued progress of the combustion zone through the stratum, inverse air injection has been resorted to. By this technique, a combustion zone is established around an ignition borehole by any suitable means and air is fed thru the stratum to the combustion zone from one or more surrounding boreholes.

One of the major difficulties, and perhaps the biggest difficulty in the recovery of hydrocarbons by in situ combustion is the initiation and maintenance of a spontaneous, stable, and dependable combustion-ignition condition. A number of field tests in in situ combustion attempts have failed, and perhaps solely, for failure to ignite properly a porous granular rock matrix saturated by heavy hydrocarbons at some local remote location.

Large amounts of tar sand deposits, sale deposits, or other petroliferous beds, such as lignite and bituminous coal are located near the surface of the earth. Quite frequently they are covered only by a relatively shallow layer of top soil. It is with the recovery of hydrocarbons from carbonaceous strata of this character and position with which the invention is concerned.

One of the objects of the invention is to provide a process and apparatus for the recovery of hydrocarbons from a carbonaceous stratum lying adjacent the top soil or other porous stratum at the ground surface. Another object is to provide a process and apparatus which readily establish a combustion zone or front over an extensive area of a carbonaceous stratum so as to insure the maintenance of a spontaneous, stable, and dependable combustion-ignition condition. A further object of the invention is to provide a process for recovering hydrocarbons from a carbonaceous stratum of low permeability whereby the stratum is rendered more permeable and amenable to production by in situ combustion. Other objects will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises heating the upper section of a carbonaceous stratum lying just under the top soil so as to fluidize and retort hydrocarbons from

the stratum whereby they may be recovered from a lower level of the stratum thru one or more boreholes therein, either with or without the aid of fracturing. The upper section of the carbonaceous stratum is heated by heat generated and applied to the ground surface by burning a combustible mixture of O_2 and fuel within an enclosed combustion zone utilizing the earth's surface as the bottom closure.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing of which FIGURE 1 is an elevation, partly in section, of one arrangement of apparatus in a stratum illustrating an embodiment of the invention; FIGURE 2 is a plan view of apparatus similar to that of FIGURE 1; and FIGURE 3 is an elevation, partly in section, of an apparatus in a borehole for effecting an embodiment of the invention.

Referring to FIGURE 1, stratum 10 comprising a tar sand or other carbonaceous material is penetrated by a series of boreholes 12 each of which is provided with a casing 14 and well tubing 16. Casing 14 is perforated by holes 18 thru which horizontal fractures 20 are formed by fluid pressure in conventional manner. Fractures 20 around the different boreholes connect or closely overlap. Stratum 10 is covered by a thin layer of soil 22 which may be several inches to several feet in thickness. If desired the major portion or all of the top soil may be removed prior to production.

A cover 24 over a selected area of stratum 10 comprises an insulated layer 26 provided with a reflecting layer 28 on the underside thereof. Cover 24 is spaced from the ground surface a suitable distance in the range of several inches to a foot or two and is closed at its periphery by a down turned edge or peripheral wall 30 which seals with a supporting foundation 32 embedded in the soil and extending into the stratum so as to prevent substantial leakage of combustion gas or air (during in situ combustion) back to the surface outside of cover 24 without passing downwardly thru the stratum as intended. Cover 24 incloses a combustion zone 34. Any number of supports 36 having transverse passageways 38 may be utilized to support the cover.

Layer 26 of cover 24 may comprise a cement-asbestos composition, commercially available in strong sheet form, which may be joined in rectangular sections to provide any desired size cover. A suitable metal foil such as aluminum foil, on the underside of cover layer 26 serves as reflecting surface 28. Other refractory materials which are good insulators and reflectors may be utilized. The cover may be made in portable sections for transport to adjacent and remote locations on the same or other strata.

The air and fuel injection system comprises a manifold 40 connecting with any number of injection lines 42 which extend into combustion zone 34 thru cover 24 in sealed relation therewith. These injection lines may terminate in burners or fuel injection nozzles and they may be provided with any suitable means for preventing flashback. After combustion has been initiated in stratum 10, as along the combustion front 44, manifold 40 is utilized to supply air or other O_2-containing gas, such as diluted air or oxygen-enriched air, for feeding and driving the combustion front thru the stratum.

Referring to FIGURE 2, cover or enclosure 24 covers a selected section or area of stratum 10 which is penetrated by a series of in-line wells or boreholes provided with casings 14 and tubing 16. Gas manifolds 40 are uniformly spaced with respect to the well pattern running parallel and intermediate the lines of wells and connecting with a gas supply header 46. An air supply line 48 and a fuel supply line 50 connect with header 46 to supply a combustible fuel mixture and/or ignition air to the gas distribution and burner system comprising

gas injection conduits 42 connecting with manifolds 40.

In FIGURE 3, a packer 52 around tubing 16 in casing 14 packs off an upper section of the annulus. A series of fractures 54 effected thru holes 56 around the various well bores are positioned above fractures 20. The fire front 44 has just reached or has passed fractures 54, moving downwardly at the stage of operation illustrated. This arrangement of apparatus permits inverse burning at a given stage of operation and is more fully discussed below.

In operation, a combustible mixture supplied by the gas distribution system is burned in combustion zone 34 and the hot combustion gases are forced thru the porous surface layer 22 into permeable stratum 10 to fractures 20 whereby solid, semi-solid, and relatively viscous hydrocarbon liquids are rendered more fluid by the heat imparted thereto and are caused to flow and to be driven into the fractures from which they are recovered thru boreholes 12 and tubing 16 in conventional manner. In a stratum of low permeability, it is necessary to position fractures 20 and 54 at a level in stratum 10 relatively close to the upper surface of the stratum. An alternative method is to fracture the stratum vertically around well bores 12, in conventional manner, so as to provide vertical passageways at frequent intervals around each well bore for passage of combustion gas and fluidized hydrocarbons vertically thru the stratum and into the well bore at a lower level therein. Where vertical fracturing is effected thru longitudinal slots in casing 14, the uppermost sections of the slots may be plugged in conventional manner after fracturing so as to direct the flow of gas deeper into the stratum before it can flow laterally into the borehole thru the casing.

In producing non-permeable strata and strata of low permeability which require vertical fracturing to render the stratum permeable enough for production by the method of the invention, the heating phase of the process retorts hydrocarbons from the strata and renders the same sufficiently porous to permit production of the remaining hydrocarbons by in situ combustion. By fracturing and heating the stratum successively to greater depths until the bottom of the stratum or some desired level has been reached, thereby rendering the stratum porous to said level, the remaining hydrocarbon can be effectively produced by in situ combustion as hereinafter described.

Assuming the stratum 10 is sufficiently permeable either initially or after retorting hydrocarbons therefrom as previously described, production by in situ combustion is effected by suddenly or gradually cutting off the flow of fuel thru the gas distribution system, such as by closing the valve in line 50 (FIGURE 2) when the upper surface of stratum 10 is at ignition temperature, and continuing the injection of air in stoichiometric excess of the fuel. This procedure ignites the carbonaceous material in stratum 10 so as to establish a combustion front such as illustrated at 44 in FIGURE 1. Continued injection of air after ignition is effected drives the combustion front downwardly thru stratum 10 whereby hydrocarbons produced by the combustion and heating pass thru the stratum into boreholes 12 by means of fractures 20 where such fractures are utilized in the process. In operation in which a system of fractures 20 is utilized at successively deeper levels in the stratum, recovery of hydrocarbons from the fractures at the uppermost level is effected until the combustion front approaches the fractures or even arrives there at which time the casing and/or stratum at that level is plugged so that the combustion front is driven to the next lower level, produced hydrocarbons being recovered at said lower level until the combustion front arrives or approaches same and so on until the combustion front is driven to the lowermost level of the stratum with production of substantially all of the hydrocarbon material traversed by the combustion front.

It is also feasible to move the combustion or fire front 44 thru the stratum from a higher level to a lower level therein as illustrated in FIGURE 3. When the fire front 44 is driven at least into fractures 54 the flow of air thru the gas distribution system associated with cover 24 is terminated and that system is closed to flow. Air is then injected thru tubing 16 so that it flows from fractures 20 to the fire front adjacent fractures 54 and causes the front to move downwardly inversely to the flow of air. Produced hydrocarbons and combustion gas enter the annulus thru holes 56 and are recovered thru line 17 during this phase of the process. When the fire front reaches fractures 20, the inverse burning phase may be continued in the same manner by lowering tubing 16 and packer 52 to a lower fracture level.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

I claim:

1. A process for recovering hydrocarbons from a carbonaceous stratum adjacent the surface of the ground which comprises enclosing a substantial area of said surface to provide an enclosed heating chamber; heating said surface from a heat source within said chamber so that the adjacent stratum is heated and hydrocarbons therein are rendered more fluid; draining the resulting more fluid hydrocarbons from said stratum into at least one borehole penetrating same; and recovering more fluid hydrocarbons from said borehole.

2. The process of claim 1 wherein said stratum is fractured at an upper level around said borehole and at a lower level around said borehole and further comprising injecting air thru said chamber into the ground; forcing said air into the hot stratum so as to establish a direct burning combustion front; continuing injection of air thru said chamber so as to drive said front to the upper fracture; thereafter injecting air thru said borehole into the lower fracture so as to force same upwardly to the combustion front thereby moving said front thru said stratum to the lower fracture by inverse drive; and recovering hydrocarbons produced by both the direct and inverse drives thru the upper fracture and said borehole.

3. The process of claim 1 wherein said stratum around said borehole is fractured and hydrocarbons are drained into said borehole thru said fractures.

4. The process of claim 1 wherein said heat is applied by burning a combustible gaseous mixture of fuel and air in said chamber and the resulting hot gases are forced into the ground and thru a section of said stratum so as to heat same to ignition temperature of the carbonaceous material therein.

5. The process of claim 4 further comprising injecting O_2 into the hot section of stratum so as to contact and ignite same and establish a combustion front along the top section of said stratum; and moving said front thru said stratum by feeding O_2 thereto so as to produce hydrocarbons from said stratum.

6. The process of claim 5 wherein air is injected into said stratum from above thru the ground, said front is moved by direct drive toward the bottom of said stratum and hydrocarbons produced by the combustion are recovered thru said borehole.

7. Apparatus for recovery of hydrocarbons from a hydrocarbon-bearing stratum just below a thin overburden and close to the ground surface which comprises an insulating cover over an extended area of said surface having a peripheral wall extending into the ground to form a seal therewith, thereby providing an enclosed heating chamber; means for applying heat to the ground within said area so as to heat said stratum and fluidize hydrocarbons therein; and means for recovering resulting fluidized hydrocarbons produced by said heating from a selected level below the top surface of said stratum below said cover.

8. The apparatus of claim 7 wherein said means for recovering hydrocarbons comprises at least one borehole penetrating said stratum below said cover including a casing and tubing string extending thru said cover for flow of fluids therethru.

9. The apparatus of claim 7 wherein said means for recovering hydrocarbons comprises a series of parallel in-line boreholes provided with casing extending thru said cover; tubing in said casing for recovering hydrocarbons; and wherein said means for applying heat comprises a fuel-air injection system having injection conduits extending into said heating chamber at regular intervals both along the line of boreholes and transverse thereto.

10. The apparatus of claim 7 wherein said means for recovering hydrocarbons comprises at least one borehole in said stratum provided with casing extending thru said cover; tubing in said casing extending from the surface to a lower level of fractures in said stratum around said borehole; a packer between said casing and tubing packing off a section of casing annulus intermediate said lower level of fractures and an upper level of fractures in said stratum around said borehole; openings in said casing at each fracture level; and a production line leading from the upper end of said casing.

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