

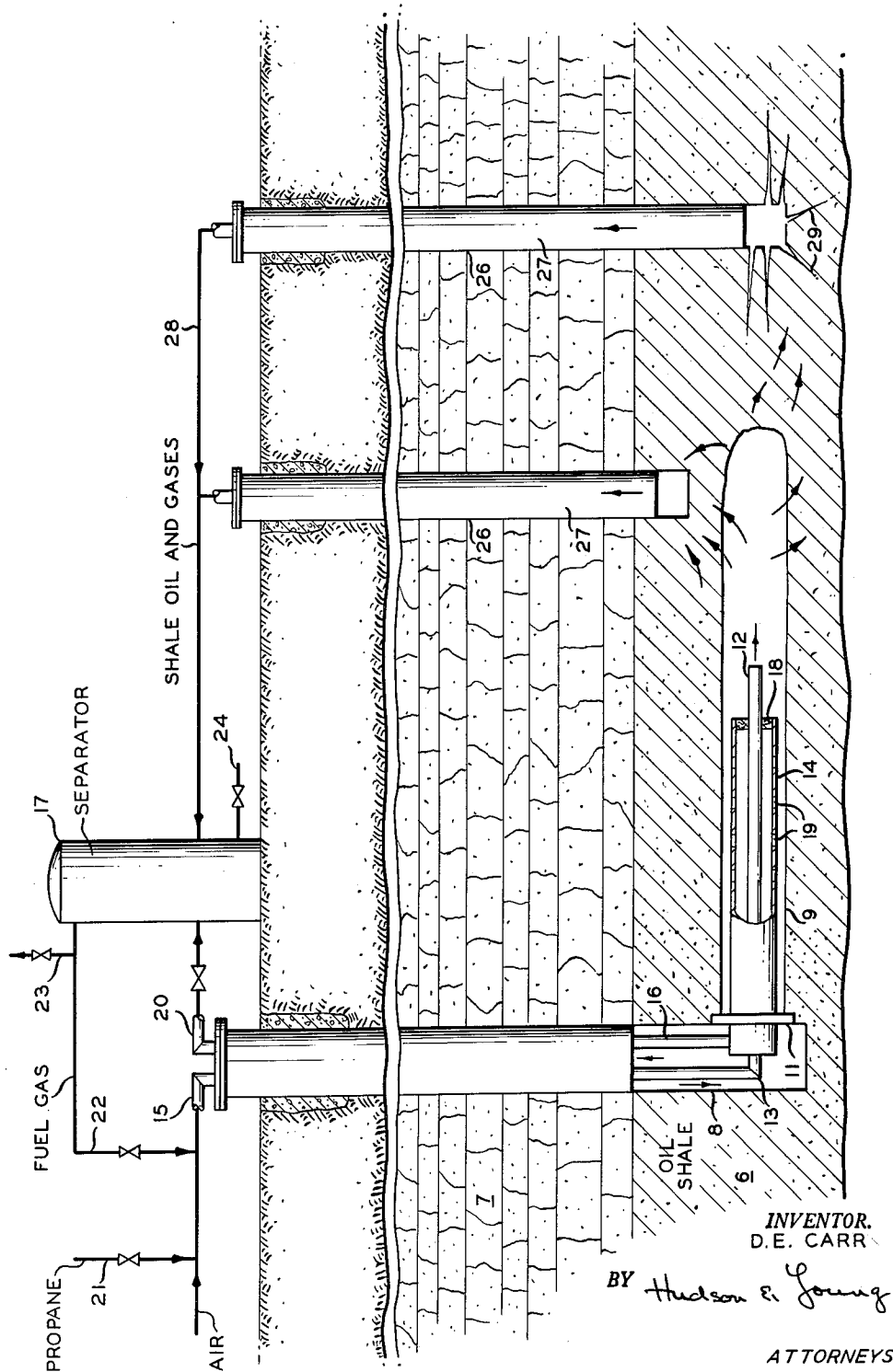
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IN SITU RETORTING OF OIL SHALE

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IN SITU RETORTING OF OIL SHALE

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This invention relates to the in situ retorting of oil shale to recover shale oil. In one aspect, it relates to a method and apparatus for producing or recovering shale oil from oil shale without removing the latter from its natural location or position in the ground.

Oil shale is a compact sedimentary rock containing organic material (kerogen) which is nonflowable at normal temperatures but convertible to volatilizable constituents or shale oil by heat or pyrolysis. Conventional methods of recovering shale oil involve mining the oil shale, either by the open-pit technique or by underground mining, crushing the mined oil shale, and transporting it to retorts. These conventional methods are time consuming, require a great deal of equipment, and are relatively expensive.

The subject invention overcomes to a great extent the disadvantages of the aforementioned conventional oil shale mining and retorting methods, and has among its objects and advantages the following: One object of this invention is to provide a method for the in situ retorting of oil shale. Another object is to provide apparatus for carrying out such a method. Another object is to produce or recover shale oil from oil shale without removing the latter from its natural location in the ground. Another object is to provide an in situ retorting process for the production of shale oil whereby close and effective control can be exercised over the air supplied and consumed during the retorting process, and over the advance of the flame front in the oil shale stratum wherein the retorting process is carried out. Another object is to provide an improved in situ retorting process for the production of shale oil, which process requires a minimum amount of mining, if any, and a minimum amount of surface equipment. Another object is to provide an in situ process for the retorting of oil shale which obviates the use of surface retorting equipment. Another object is to provide the production of volatilizable constituents produced by the in situ retorting of oil shale. Further objects and advantages of this invention will become apparent to those skilled in the art from the following discussion, appended claims, and accompanying drawing wherein the single figure diagrammatically illustrates, in vertical section, an oil shale stratum or formation, and the apparatus of this invention.

Referring now to the single FIGURE of the drawing, an oil shale stratum or formation 6 is illustrated, with overlying, generally impervious, nonproductive strata or formation 7 thereabove, penetrated or traversed by a mined or drilled access shaft 8 which can be supported or cased by any known technique. A relatively horizontal borehole 9, sometimes referred to as a "blind borehole," is drilled from access shaft 8 into the oil shale stratum 6 and extends therein. The outer end of borehole 9 can be sealed by any suitable means, such as by casinghead 11, which can be cemented or otherwise secured to the exposed face of the oil shale stratum 6. Extending through casinghead 11 and into the open borehole 9 is an air injection conduit or pipe 12, the end of this pipe which extends into the shaft 8 being connected to a suitable vertical conduit or pipe 13 which leads to the surface of the ground and is connected by pipe 15 to a suitable source of air or other free oxygen-containing gas, which can be preheated if necessary. Also, extending within borehole 9 is an exhaust conduit or pipe 14 which is preferably disposed in annular relation with air injection pipe 12, the annulus

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between these two pipes communicating with a vertical conduit or exhaust pipe 16 in shaft 8, the upper end of this exhaust pipe being connected by pipe 20 to a separator tank 17 at the surface, this tank being of conventional design and adapted to separate condensable oil vapors from relatively non-condensable gases; if desired, separator 17 can have disposed therein suitable cooling equipment, such as water coils for the liquefaction of condensable vapors. The air injection pipe 12 and/or exhaust pipe 14 can be made of any heat-resistant material, such as ceramic or the like. The annular space between air injection pipe 12 and exhaust pipe 14 is preferably sealed at its inner extremity by means of any suitable seal or packer 18, and the exhaust pipe can be provided with a plurality of perforations or other openings 19 along the length thereof. The surface air injection pipe 15 can be connected by pipe 16 to a suitable supply of fuel gas, such as propane, butane, liquefied petroleum gas, etc. Pipe 15 is also preferably connected to another fuel gas pipe 22 which is connected at its other end to the upper end of separator 17. This latter fuel gas pipe can be connected to a side pipe 23 which can in turn be connected to suitable gas storage tanks. Separator tank 17 can also be provided with a suitable oil withdrawal pipe 24 which can lead to suitable oil storage tanks.

Oil shale stratum 6 is transversed by one or more product recovery wells 26. These recovery wells can be drilled by conventional well drilling techniques and provided with vertical piping or casing 27 which is connected at the surface to a product line 28 which in turn is connected to separator 17. The lower ends or open boreholes of recovery wells 26 are disposed in proximity to the borehole 9 and can be either above or below, or at the same level as, the borehole 9. If desired, the oil shale stratum adjacent the lower ends of recovery wells 26 can be fractured by conventional techniques so as to provide fractures or fissures 29 to aid in the recovery of the products resulting from the retorting operation.

Although the drawing illustrates an oil shale stratum communicating with a vertical shaft 8, it is within the scope of this invention to carry out the retorting of the oil shale in a stratum exposed at the face of a slope or cliff as an outcrop. Moreover, the subject invention can be carried out in an oil shale stratum exposed by open pit mining process. More than one blind borehole can be provided, communicating with the same or other adjacent access shafts.

In operation, the combustion of the oil shale stratum is initiated by any suitable means. For example, a stoichiometric, or oxygen-rich, mixture of air and propane or butane, the latter hydrocarbons being supplied by fuel gas pipe 21, is pumped under suitable pressure (e.g., 10 p.s.i.g.) via vertical pipe 13 and injection pipe 12 into the open borehole 9 and this mixture is ignited within the borehole by any suitable means, such as an electric spark, or the like, the flame temperature being sufficient to initiate combustion, e.g., 500–3000° F. As a result, the combustion of a portion of the oil shale stratum 6 is initiated and the resulting combustion gases and initial oil vapor and gaseous pyrolysis products are removed from the borehole via inlets 19 and the annulus between injection pipe 12 and exhaust pipe 14, and these gases are conveyed to separator tank 17 via pipes 16 and 20.

Alternatively, the combustion of the oil shale stratum 6 can be initiated by any other suitable technique, for example, by packing the open borehole 9 with charcoal and igniting the same by supplying air or other free oxygen containing gas, per se, or in admixture with a small amount, e.g., 2–3 percent, of a fuel gas, such as propane.

After the combustion of a portion of the oil shale stratum 6 has been initiated, this combustion can be sus-

tained by continuously supplying air from the surface and injecting it into the borehole, or by supplying this air in admixture with either propane, butane or the like. Alternatively, this air can be admixed with some of the initially produced uncondensed fuel gas by recycling the same via line 22 from separator 17 to the air supply pipe 15.

As combustion of the oil shale stratum proceeds, a fire front or combustion zone, having a temperature of about 1000-3000° F., progresses through this formation, as indicated in the drawing by the directional arrows, and decomposes the kerogenic material. The resulting products produced by the in situ retorting and combustion process, which products comprise condensable oil vapors or normally liquid constituents and relatively noncondensable gaseous pyrolysis products, as well as combustion gases, migrate upstream toward recovery wells 26 and are produced therefrom and conveyed to separator tank 17 via surface pipe 28. If necessary the air injection pipe 12 can be progressively extended into the borehole 9.

During the retorting process of this invention, the composition of the oxygen or combustion supporting gas and the fire front or combustion front can be always controlled at the surface so as to regulate and control the retorting reaction. As the oil shale stratum becomes depleted, more recovery wells can be drilled at distances progressively removed from the depleted stratum.

It is thus seen that the practice of the subject invention is not time consuming, and does not entail the use of expensive retorting equipment. The retorting of the oil shale is carried out in its natural location in the ground and thus dispenses with the necessity of providing oil shale crushing and conveying equipment or spent shale handling and discarding equipment. Moreover, the subject invention can be practiced where the oil shale is relatively widely dispersed underground in relatively poor yield pockets, or where oil shale formations cannot be safely or feasibly mined by conventional techniques.

Various modifications and alterations of this invention will become apparent to those skilled in the art from the foregoing discussion and accompanying drawing, and it should be understood that the subject invention is not to be unnecessarily limited to the preferred embodiments set forth hereinbefore.

I claim:

1. A method for the in situ retorting of oil shale, comprising the steps of drilling a horizontal blind borehole into an oil shale stratum, which is a compact sedimentary rock containing a solid organic material, kerogen, said kerogen being convertible to shale oil by heat and pyrolysis, drilling a first group of vertical recovery wells into said stratum in proximity to said borehole, supplying a mixture of fuel gas and oxygen-containing gas to said borehole, igniting said mixture within said borehole to establish a combustion zone, continuously supplying oxygen-containing gas to said borehole to maintain said combustion zone and cause it to advance generally horizontally through said stratum in a direction toward said recovery wells, recovering the resulting products of retorting and combustion from said stratum through said first group, drilling a second group of vertical recovery wells at a distance removed from the resulting depleted area of said stratum about said first group; and continuing the afore-cited sequence of steps of supplying fuel gas and oxygen-containing gas and recovering the resulting products from said stratum through said second group.

2. A method for the in situ retorting of oil shale, comprising the steps of drilling a horizontal blind borehole into an oil shale stratum, which is a compact sedimentary rock containing a solid organic material, kerogen, said kerogen being convertible to shale oil by heat and pyrolysis, drilling a first group of vertical recovery wells into said stratum in proximity to said borehole, supplying a mixture of fuel gas and oxygen-containing gas to said borehole, igniting said mixture within said borehole to establish a combustion zone, continuously supplying oxygen-containing gas to said borehole to maintain said combustion zone and cause it to advance through said stratum in a generally horizontal direction toward said recovery wells, withdrawing from said stratum the resulting gaseous and vaporous products of retorting and combustion through said first group, passing the withdrawn products to a separation zone for separating said gaseous and vaporous products, drilling a second group of vertical recovery wells at a distance removed from the resulting depleted area of said stratum about said first group; and continuing the afore-cited sequence of steps of supplying fuel gas and oxygen-containing gas and recovering the resulting products from said stratum through said second group.

3. The method according to claim 2 wherein a portion of said separated gaseous products are recycled to said borehole.

4. A method for the in situ retorting of oil shale, comprising the steps of providing a vertical shaft from ground surface to an oil shale stratum, which is a compact sedimentary rock containing a solid organic material, kerogen, said kerogen being convertible to shale oil by heat and pyrolysis, drilling a blind borehole from said shaft into said stratum, drilling a first group of vertical recovery wells from ground surface to said stratum at points spaced from said borehole, supplying a mixture of fuel gas and oxygen-containing gas to said borehole, igniting said mixture within said borehole to establish a combustion zone, passing the resulting combustion products from said borehole to a separation zone located at ground surface via said access shaft, continuously supplying oxygen-containing gas to said borehole to maintain said combustion zone and cause it to advance generally horizontally through said stratum in a direction toward said first group, withdrawing from said stratum the resulting gaseous and vaporous products of retorting and combustion through said recovery wells, passing the withdrawn product to said separation zone for separating said gaseous and vaporous products, drilling a second group of vertical recovery wells at a distance removed from the resulting depleted area of said stratum about said first group; and continuing the afore-cited sequence of steps of supplying fuel gas and oxygen-containing gas and recovering the resulting products from said stratum through said second group.

5. The method according to claim 4 wherein said fuel gas is selected from the group consisting of propane, butane and liquefied petroleum gas.

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