

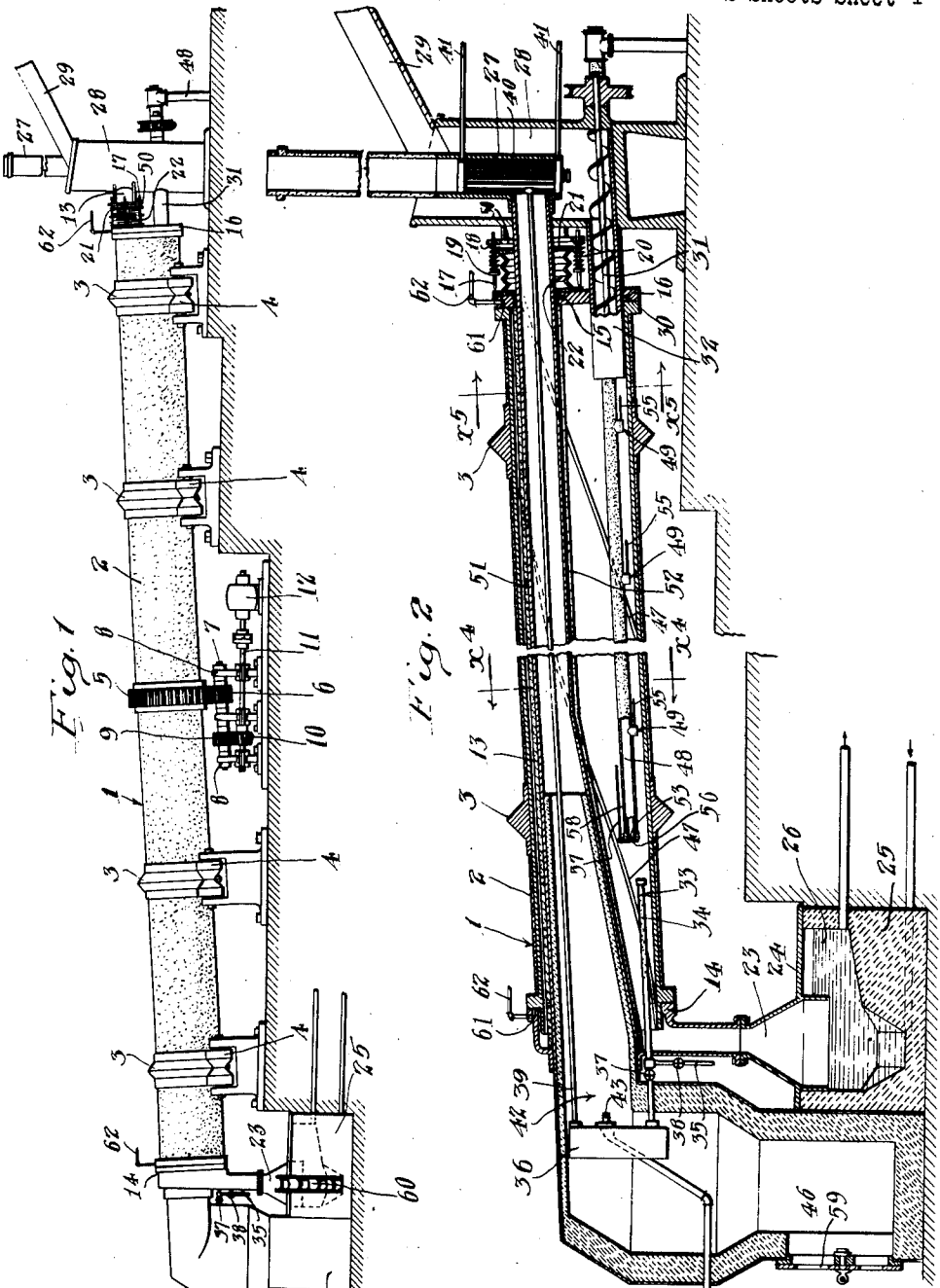
March 29, 1927.

J. J. JAKOWSKY

1,622,722

PROCESS OF AND APPARATUS FOR DISTILLING BITUMINIFEROUS MATERIAL

Original Filed Aug. 12, 1920 2 Sheets-Sheet 1



Witness:
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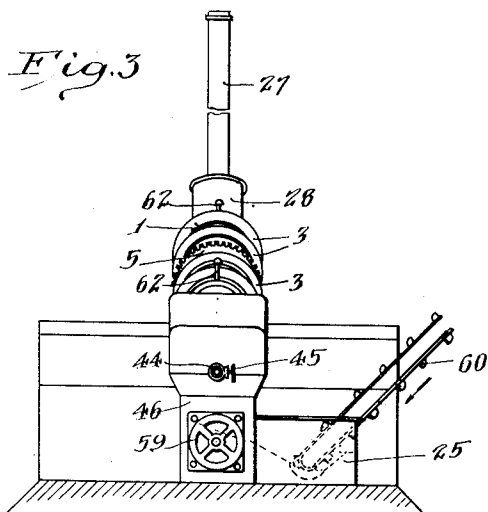


Fig. 5

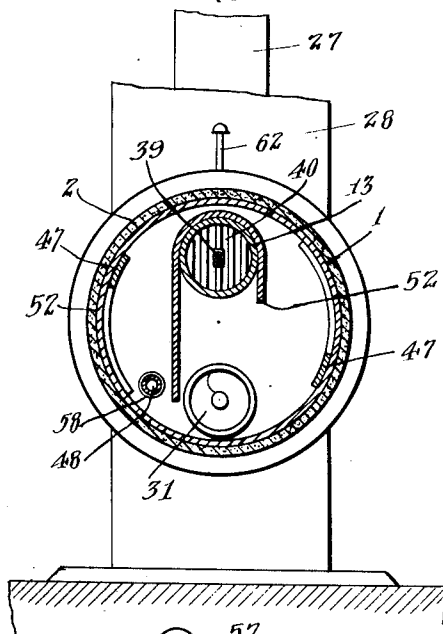


Fig. 4

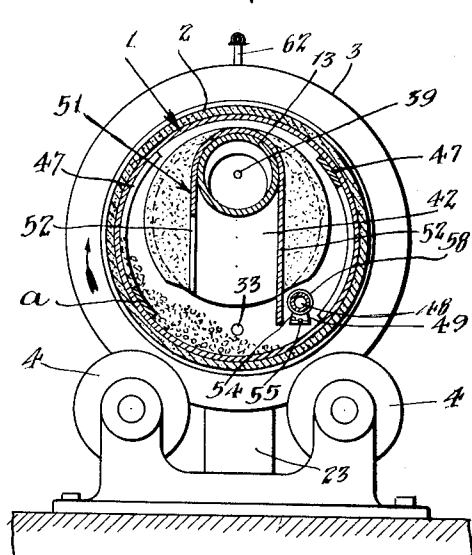
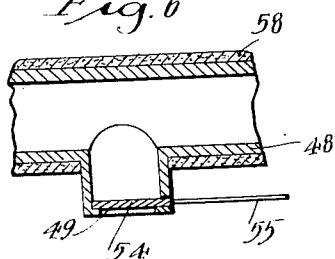


Fig. 6



Witness:
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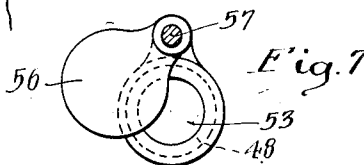


Fig. 7

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PROCESS OF AND APPARATUS FOR DISTILLING BITUMINIFEROUS MATERIAL.

Application filed August 12, 1920, Serial No. 403,097. Renewed January 11, 1926.

This invention relates to a process of distilling material, and especially that character of material containing bituminiferous matter or, as it is frequently termed, a "kerogen". Examples of bituminiferous solids which may be advantageously treated by this process are shales, coal, peat and lignite. Bituminiferous matter, upon destructive distillation thereof, yields oily and tarry products resembling crude petroleum, termed in this art a hydrocarbon.

The invention not only relates to the process, but also to a special apparatus in which the various operations of the process may be performed.

By prior processes and apparatus, during the operation of distilling the material, conduction by the material of the heat employed for the distillation of the material takes place to a relatively great extent, and also in many forms of apparatus of this character some heat reaches various portions of the body of the material, especially that in the center of the mass, by convection.

Because of the comparatively low thermal conductivity of the class of materials to be treated by this retort, the outside portion of the mass undergoing distillation, especially after the oil vapors are driven therefrom, soon rises to a higher temperature than that of the interior of the mass still undergoing distillation, and as a result some of the vapors from the interior of the mass in passing through the outer and more highly heated portion of the mass are subjected to a temperature higher than that required for their formation, causing decomposition and cracking. It is a well known fact that when hydrocarbons are cracked, though the yield of hydrocarbons of a relatively lower specific gravity is increased, the hydrocarbons of the paraffin and other series which are of value as lubricants are largely destroyed, and also the volume of the oil is decreased.

If the time of treatment of the material in many of the present retorts is too short, one of two things will happen because of the poor thermal conductivity of the shale; either the material in the interior of the charge will not yield its full percentage of oil; or the rising temperature of the outer portions of the material will be greater than that usually required for the destructive distillation of the oil. When the latter hap-

pens the oil vapors coming from the more central portions of the mass of the material will be decomposed when passing through the outer or more highly heated portions, causing the formation of a greater percentage of uncondensable gas and a poorer grade of oil. By a series of experiments it has been determined that the maximum yield of oil of high grade is obtained by causing the material to gradually reach the temperature of complete distillation. The bad effects of heating the material too quickly are more pronounced in those retorts wherein a considerable thickness of the column of the material must be penetrated by the heat in order to reach the center of the charge; in other words, in those retorts depending to a more or less extent upon the thermal conductivity of the shale itself to carry the heat necessary for the destructive distillation of the material in the center of the mass. To effect the heating I provide a relatively long retort, for example, a retort of about 60 feet in length, and progressively heat said retort from the inside.

In many of the present retorts, the percentage of oil recovered is usually somewhat less than the theoretic amount. Because of the poor thermal conductivity of the material undergoing distillation, in those retorts where a considerable thickness of the material must be penetrated by the heat necessary for the destructive distillation of the bituminous matter in the interior of the mass, the time of operation will be greater than that required in those retorts where only a comparatively shallow bed of the material must be penetrated by the heat, in order for the correct amount of heat to reach the material in the center of the mass for the maximum recovery of oil therefrom. During the process of destructive distillation more or less uncondensable gas is produced for which there is usually no great commercial demand and which can be used as fuel for supplying the necessary heat for the operation of the process. In those retorts where a considerable thickness of the material must be penetrated by the heat, the time of operation compared to through-put is of such length that the heat value of the uncondensable retort gases is not sufficient to keep the retort supplied with the proper number of B. t. u., and as a result one of two things must be done: Either the process

must be stopped short of complete eduction of the oil; or additional fuel must be supplied in the form of some of the recovered oil, or raw shale must be used for fuel, or some other fuel supplied, causing a waste of hydrocarbons. In this process, the method of heating coupled with the efficient construction of the retort, utilizes the heating value of the gas to such an extent that it has not been found necessary to add additional fuel for the carrying on of the process, thereby conserving the hydrocarbons. Also because of the temperature used at the discharge end of the retort, the recovery of oil is practically complete before the shale has fully approached the discharge end of the retort.

I guard against subjecting the hydrocarbon vapors or the material undergoing distillation to high temperatures since one of the chief factors in the obtaining of the maximum eduction of oil from the bituminiferous material is the application thereto of a temperature which will just decompose the bituminiferous material for the formation of the hydrocarbon. Low temperatures are conducive to the formation of the easily condensed paraffin compounds, while pyrogenic decomposition causes the formation of a greater percentage of the uncondensable gases and unsaturated hydrocarbon compounds.

In the Scottish type of retort, when the steam is not used, because of the low thermal conductivity of the shale a large portion of the shale nearer the wall of the retort will reach the distillation temperature before the shale in the interior of the column. In consequence of this the oil is driven off of the shale adjacent the wall of the retort before that in the center has reached the required temperature for recovery of the maximum percentage of oil. The temperature of the outermost shale, after the oil is driven therefrom, will continue to rise until it is much higher than that of the inner shale undergoing distillation, and receiving its heat by conduction and convection. Also the volume of the spent shale will decrease slightly and this together with the downward enlargement of the retort permits the shale to shrink away from the hot wall of the retort, leaving an annular space which provides for ready escape of the oil vapors coming from the shale in the interior of the mass. As a result, the oil vapors pass through the hot zone adjacent the retort wall and also come into contact with said wall and are thus subjected to a temperature far above that required for their eduction, causing decomposition and cracking of the vapors and consequent loss of hydrocarbons of the paraffin series for the formation of a greater percentage of unsaturated hydrocarbons.

I have prevented this pyrogenic decomposition of the vapors by placing the vapor line at approximately the position indicated on the drawings, that is to say in the lower portion and to one side of the retort. The nascent hydrocarbon vapors upon being distilled from the material undergoing destructive distillation, are immediately drawn away from the material and from the heat radiating surface into a cooler zone (cooler because of it being farther away from the heat-radiating conduit) and thence into the vapor line which is preferably covered with a heat insulating material. Decomposition of the vapors is thereby largely prevented since at no time are the vapors allowed to come into contact with a heated surface or zone at a higher temperature than that required for their formation.

Also in the Scottish type of retort the hot vapors coming in contact with the cooler shale at the upper portion of the column condense and are carried downwardly to the hotter zone, thus causing redistillation. I have found that when hydrocarbon vapors are allowed to condense five times before being removed from the retort, as is liable to happen in the types of retort mentioned above, a loss of about twenty-five percent of the total volume of the oil results. After five redistillations the Baumé gravity increases from 22.9 to 35.80 due to the cracking which is destructive to the paraffin series.

I have prevented the liberated vapors from coming into contact with the cooler incoming shale by the arrangement above referred to of the vapor outlet or line. At no time are the vapors allowed to come into contact with the shale but are immediately drawn into the vapor line which, although slightly cooler than the shale undergoing distillation, is not cool enough to permit condensation of any of the hydrocarbon vapors. The losses due to redistillation are thereby prevented.

In the Scottish retort, as well as others in which a vertical column of material is formed, the pressure in the lower portion of the column decreases the porosity of the column and thus hinders the escape of the vapors and gases. The vapors are thus confined too long a time and are carried down to the hotter zone where decomposition of said vapors is liable to occur. By my process and apparatus I avoid column pressure.

An important object of this invention is to recover the hydrocarbons with a minimum amount of cracking thereof so as to obtain many of the paraffins and lubricants which would be lost if the prior processes be employed.

Another important object is to effect a maximum production of ammonia vapors so that said vapors may be employed in the manufacture of important chemical products

such, for example, as certain compounds useful as fertilizers.

Subsidiary objects of the invention are:

To effect continual agitation of the material being treated and to cause movement thereof to different positions within the body of the material, in a manner to continuously expose fresh surfaces of the material to the radiated heat which is supplied for producing the destructive distillation of the material:

To apply heat only to the upper surface of the material by direct radiation, and not to the material in the interior of the mass by conduction through the agency of the material nor convection through the agency of the vapors and gases given off by the material when heated or by vapors or gases, such as steam, etc., introduced into the retort. By thus applying the heat by direct radiation, contact of the material is avoided with the wall through which the heat is conducted and from which it radiates, thus practically avoiding cracking of the hydrocarbons, which cracking occurs in many of the retorts employing heated walls or surfaces in direct contact with the throughgoing shale for supplying the heat necessary for destructive distillation of the bituminiferous material:

To accomplish withdrawal of the liberated vapors and gases without their being subjected to recontact with the material from which they have been liberated, or contact with fresh material entering the distilling zone, thus avoiding condensation upon said material within said zone.

For the accomplishment of the results noted above I provide a heating conduit in the upper portion of the retort in which the material is treated, and means are provided for continuously stirring and agitating the material so as to bring all portions thereof to the surface of the body of the material in order that all of said material may be exposed at intervals to the maximum degree of heat at the surface where the vapors and gases are given off in maximum volume. In the particular apparatus illustrated the agitation and stirring of the material as well as flow thereof is effected by slowly rotating the retort.

The accompanying drawings illustrate an apparatus built in accordance with the provisions of this invention:

Figure 1 is a side elevation of the apparatus in which the new process may be performed.

Fig. 2 is a longitudinal mid-section of the apparatus shown in Fig. 1.

Fig. 3 is an end elevation from the left of Fig. 1.

Fig. 4 is a sectional elevation on line indicated by X⁴-X⁴, Fig. 2.

Fig. 5 is a sectional elevation on line indicated by X⁵-X⁵, Fig. 2.

Fig. 6 is an enlarged sectional detail of a portion of the gas eduction conduit showing one of the valves therefor.

Fig. 7 is an enlarged elevation of the inner end of the gas eduction conduit showing the end valve.

The apparatus shown in the drawings is the one which I at present prefer for performing the new process, but it is to be understood that said process may be carried out by any other suitable apparatus. In the apparatus illustrated I provide a rotating retort 1 in the form of a cylinder or drum, insulated against appreciable loss of heat by a jacket 2 of heat insulating material. The retort 1 is provided with bearing rings 3 adapted to turn upon the rollers of anti-friction bearings indicated at 4. For rotating the retort it is provided with a gear 5 meshing with a pinion 6 on a shaft 7, which is journaled in suitable bearings 8. The shaft 7 is provided with a gear 9 meshing with a gear 10 on a shaft 11 operated by a suitable motor 12. The motor 12 may be operated by electricity or otherwise so as to cause rotation of the retort 1. The speed of rotation of the retort is preferably low, for example a third of a revolution per minute.

The retort 1 is preferably mounted on its bearings in an inclined position as shown in the drawings, and extending from end to end of the retort and projecting therefrom at both ends is a heat radiating tube or conduit 13. The conduit 13 is positioned in the upper portion of the retort and is larger at one end than the other, the intake end of the retort being adjacent the smaller end of the conduit and the discharge end being adjacent the larger end of said conduit. The conduit is gradually reduced from its larger end for substantially a third of its length, though the length of taper may be more or less as desired.

The conduit 13 is protected on its sides and top against loss of heat by radiation laterally and upwardly by a suitable heat-insulating jacket 51 of inverted U-shape construction in cross section, the sides of said jacket forming heat-directing flanges 52 adapted to direct the heat radiated by the conduit downwardly upon the upper surface of the shallow bed of material α being treated and to deflect the heat radiated by the sides of the conduit toward the more central portion of the retort. The jacket 51 also prevents direct radiation to the rotating drum or kiln, and vapor line, thereby keeping said kiln or retort wall and vapor line as cool as possible.

The larger end of the conduit 13 passes through a stationary head 14, against which the discharge end of the retort 1 thrusts and the smaller end of the conduit passes through an opening 15 in a stationary head

16, that is yieldingly held against the intake end of the kiln by suitable pins or studs 17 shiftably mounted in bearings 18 formed in a ring 50. Between the bearings 18 and shoulders 19 provided on the pins 17 are coil springs 20 urging the pins against the outer face of the head 16, and thus forcing said head against the adjacent end of the retort. Fixed to the conduit 13 is a collar 21, and extending from the said collar to the head 16 and surrounding the conduit 13 is an expandible sleeve 22 constructed somewhat after the manner of a bellows, preferably of a series of thin metal rings, each of said rings being suitably fastened at its outer and inner margins to the respective adjacent rings. The collar 21 and sleeve 22 together form packing to prevent leakage of the vapors and gases from the retort and of air thereinto, and the sleeve 22 permits of movement between the head 16 and collar 21 due to differences in the amount of expansion and contraction between the retort 1 and conduit 13.

The head 14 is provided with an outlet passage 23 and said head is mounted on a cover 24 of a receptacle 25 containing a water seal 26, below the surface of which the outlet passage 23 extends, so as to seal the outlet end of the retort against the admission of air and the discharge of gases and vapors.

The smaller end of the conduit 13 communicates with a stack 27, the lower end of said stack projecting into a vertical fuel-preheating hopper 28 adapted to receive the material to be treated from a chute 29, which is fragmentarily shown in the drawings. Extending transversely in the lower portion of the hopper 28 and projecting through an opening 30 in the head 16 into the retort 1 is a screw 31 for mechanically feeding the material from the hopper to the interior of the retort. The screw 31 extends from the hopper into the retort through a tubular enclosure 32.

Means are provided for discharging steam or water into the retort and for this purpose there is shown a nozzle 33, provided with a series of outlet openings 34. The nozzle 33 extends longitudinally in the discharge end portion of the retort in the mid-plane thereof and connects with a water supply pipe 35 and also with a suitable boiler 36, which is mounted in the larger end of the conduit 13. Valves 37, 38 determine whether steam or water or both are to be admitted to the nozzle 33. The boiler 36 is connected by a tube 39, passing lengthwise through the conduit 13, with a flue preheater 40 mounted in the lower portion of the stack 27, water being supplied to the preheater through pipes 41.

The larger end of the conduit 13 forms a combustion chamber indicated at 42, and the boiler 36 is mounted in said combustion

chamber. Also positioned in the combustion chamber 42 is a burner 43 supplied with suitable fuel through a fuel pipe 44 provided with a valve 45. The lower end of the combustion chamber forms an air intake 46.

Rotation of the retort 1 tends to carry the material being treated partially up one side of the retort, so as to tumble the material over and over. To insure that the tumbling effect be sufficient for efficient operation of the retort, said retort is provided with means to assist in carrying the material part way up one side of the retort and at the same time to cause feeding or flow of the material at a predetermined rate of speed from the intake end toward the discharge end of the retort. In this instance this movement of the material is effected by suitable ribs 47 projecting from the inner face of the retort and extending aslant relative to the longitudinal axis of the retort. The slant of the retort also tends to cause movement of the material toward the discharge end thereof. The ribs 47 are especially useful to prevent slipping of the material being treated when it becomes slippery from being sufficiently heated to cause hydrocarbons to be extracted therefrom.

Extending longitudinally in the bottom portion of the retort 1, is vapor and gas eduction conduit 48 provided along its under side with a suitable number of ports 49 and at its inner end with a port 53 for withdrawal from the retort of the vapors and gases produced in the retort. The admission of vapors and gases through the ports 49 to the conduit 48 is controlled by slide valves 54 operated by rods 55 which extend to the outside of the retort, and admission of vapors and gases through the port 53 is regulated by a slide valve 56 which is turned by a rod 57 that extends to the outside of the retort. The conduit 48 is preferably insulated against the absorption of external heat by a heat-insulating covering 58 and carries the vapors and gases to any suitable apparatus for condensing and separating the different kinds of vapors, gases and liquids from one another. The air intake 46 is provided with a damper 59 to control the air entering the combustion chamber.

The container 25 is provided with a conveyor 60 of the bucket or other suitable type for exhausting the material from the container after the material has been discharged from the retort.

The process is performed in the hereinbefore described apparatus as follows: Assuming that the fuel has been ignited at the burner 43, the material to be treated, as for example oil, shale or other bituminous matter, will be discharged into the hopper 28 through the chute 29, and the screw 31 will be operated so as to pass the material into

the upper end of the retort, which is the cooler portion of the graduated hot zone inside of the retort.

The temperature of the distillation zone adjacent the discharge end of the retort will preferably be about 1500° F. and the temperature will gradually lessen toward the intake end. Preferably the temperature will not rise above 900° F. in that portion of the distillation zone in which the hydrocarbon vapors are driven off of the material. As the material passes through the retort toward the discharge end thereof, it is agitated and moved into different positions within the body of the material, the under portions of the material being carried upwardly and forwardly by the ribs 47 and falling upon the surface of other portions of the material, thus exposing the material uniformly to heat radiated from the wall of the conduit 13. It is to be particularly noted that the heat is applied to the upper surface of the material, and that heating of the material to the requisite temperatures is not dependent upon conduction of heat by the material itself. It is also important that heating of the material to the requisite temperature is effected without convection.

The material is of course preheated in the hopper 28 by heat from the stack 27, and the temperature of the material gradually increases as it moves toward the discharge end of the retort, for the reason that the source of heat is at the discharge end; for the further reason that the size of the conduit is gradually increased from near the intake end toward the discharge end, thus decreasing the distance the heat must be radiated from the hot conduit to the through-going material, thereby increasing the amount of heat radiated in any given time of operation of the retort; and also because of the tapering or nozzle shape of the conduit the gases of combustion part with the larger portion of their heat before they reach the intake or upper end of the retort. Heat is further extracted from the gases of combustion by the water preheater 40 and by the material in the hopper 28.

As noted above the temperature of the larger portion of the retort is preferably not higher than about 900° F., temperatures not higher than this obtaining in the greater portion of the retort through which the conduit portion of smaller diameter extends. This temperature is sufficient to drive off practically all of the hydrocarbon vapors before the material reaches the zone of temperature above that required to distill off the hydrocarbons. As far as oil recovery alone is concerned, it would not be necessary to raise the material to a higher temperature. Some ammonia vapors are driven off before the temperatures equal 900° F., but

much greater temperatures are necessary to obtain a greater recovery of ammonium-sulphate. These greater temperatures, however, are inimical to the recovery of hydrocarbons of the paraffin series, and I therefore draw off the hydrocarbon vapors into a slightly cooler zone before said vapors can possibly reach the more intensely heated portion of the retort, towards which portion the material is moving. It is in this more highly heated portion of the retort that the nozzle 34 is located, consequently the vapors and gases driven off from the material at temperatures greater than 1000° F. are subjected to the action of the steam which either discharges from the nozzle 34 or is instantly formed from water discharged by said nozzle. The vapors driven off from the material in this portion of the distillation zone are composed of ammonia and other nitrogen compounds, carbon monoxide and carbon dioxide, a large percentage of the latter two being formed by the action of the steam on the red hot material. The steam mixes with the hot material and thus becomes superheated and to a slight extent part of the steam dissociates into its elements, hydrogen and oxygen. The hydrogen of the steam combines with part of the nitrogen of the material being treated, reacting to form ammonia vapor NH_3 and other nitrogenous compounds, while the oxygen of the water reacts with some of the carbon remaining in the material to form the carbon monoxide and carbon dioxide gases referred to above. These by-products are drawn off through the conduit 48 together with the saturated and unsaturated hydrocarbons produced in the retort, as above described. Eduction of the vapors and gases through the conduit 48 may be effected by attaching said conduit to a suitable exhaust pump, not shown, such means for effecting the eduction being already known in the art. The vapors and gases thus drawn off are passed through suitable condensers, and the condensates are treated in a manner well understood in this art for separation and recovery of the liquid hydrocarbons and ammonia. The non-condensable gases are also treated for removal of the ammonia and the lighter oils, and later used as fuel to operate the retort for a continuation of the previously described process. The material after having the vapors and gases driven off as above described discharges into the water seal 26 which washes the potash and other soluble compounds or elements from the material, and the conveyor 60 operates to discharge the material, thus washed, from the container 25. The water will then be treated by any well known method for recovery of its potash or other chemical content.

To make the joints between the retort 1 and heads 14, 16 sufficiently tight to prevent as far as possible the passage of gases therethrough, the heads 14, 16 are provided with ducts 61 opening to the surfaces adjacent the ends of the retort and said ducts are connected by pipes 62 with a suitable supply of lubricant.

From the foregoing it will be clear that the surface portions of the bed of material *a* in the retort are progressively heated to the required temperatures while the material is moving through the zones of different temperatures in the retort; that the under portions of the material or those interiorly of the mass are moved by rotation of the retort to the surface, whereby approximately uniform distillation temperature of the material at any given vertical section of the bed is secured; that the required temperatures are produced by direct radiation without the aid of conduction, thus eliminating heating of the material to above the hydrocarbon distilling temperatures before the material reaches a predetermined zone; that steam is supplied to the material in the hotter zone; and that the vapors and gases evolved in the zones of different temperatures are drawn away from the surface portions of the material and also away from the heat-radiating conduit as fast as they are formed, whereby cracking, condensation on cooler material, and redistillation of the hydrocarbons are avoided.

It will now be understood that an important feature of this invention is the retort wherein the heat necessary for the destructive distillation of the through-going material shall be supplied only by direct radiation upon continually fresh exposed surfaces of said material undergoing distillation; and that another important feature is that at no time shall the material undergoing destructive distillation come into direct contact with the heat supplying surfaces, thereby not depending upon the thermal conductivity of the material itself to convey the heat necessary for the destructive distillation of the material.

It should also be noticed that effort has been made to absolutely prevent destructive distillation of the material excepting at the surface of the mass under going treatment in the retort. To prevent this the walls of the retort are not directly supplied with heat and also heat is not carried to the mass in the interior of the material by convection of vapors or gases. The destructive distillation of the through-going material will take place, as far as controllable, only upon the surfaces exposed to the direct radiation of heat from the conduit.

I claim:

1. In the process of distilling solid bituminiferous material, the steps of progres-

sively heating the material by direct radiation to the required temperatures in zones of different temperatures without the aid of conduction of heat by the material, drawing off the hydrocarbon vapors from the cooler zones as fast as they are formed, and treating the vapors and gases evolved in the hotter zone with steam.

2. In the process of distilling solid bituminiferous material, the steps of progressively heating only the upper surface portions of a bed of the material by direct radiation to the required temperature, moving the under portions of the material to the surface to secure uniform distillation temperature of the material at any given vertical section of the bed, supplying steam to the material in the hotter zone, and drawing the resulting vapors and gases upwardly from the surface of the material.

3. In the process of distilling solid bituminiferous material, the steps of progressively heating only the upper surface portions of a mass of the material by direct radiation to the required temperatures while said mass is moving, stirring the material to bring other portions of it to the surface, and drawing the resulting hydrocarbon vapors from the material and upwardly from the surface portions thereof.

4. In the process of distilling solid bituminiferous material, the steps of progressively heating only the upper surface portions of a mass of the material by direct radiation to the required temperatures in zones of different temperatures while said mass is moving, stirring the material to bring other portions of it to the surface, supplying steam to the material in the hotter zone, and drawing the resulting gases and vapors from the material in the zone of hydrocarbon vapor production and upwardly from the surface portions of said material.

5. In an apparatus of the character described, a retort for the material to be distilled, means on the inside of the retort to radiate heat onto the surface of the material, a conduit positioned to draw the vapors downwardly from the heat-radiating means, and a fluid supply nozzle in the retort near one end thereof.

6. In an apparatus of the character described, a rotating retort for the material to be distilled, the longitudinal axis of said retort being nearer the horizontal than the vertical, a heat-radiating conduit extending through the upper portion of the retort, and a conduit for vapor in the lower portion of the retort.

7. In an apparatus of the character described, a rotating retort for the material to be distilled, the longitudinal axis of said retort being nearer the horizontal than vertical, a heat-radiating conduit extending through the upper portion of the retort and

provided with a gradually reduced portion, and a conduit for vapor in the lower portion of the retort.

8. In an apparatus of the character described, a rotating retort for the material to be distilled, the longitudinal axis of said retort being nearer the horizontal than the vertical, a heat-radiating conduit extending through the upper portion of the retort and being of larger diameter nearer one end than nearer the opposite end, a vapor off-take conduit in the lower portion of the retort below the level of the smaller end of said heating conduit, and a nozzle in the retort below that portion of the heating conduit having the larger diameter.

9. In the process of distilling solid bituminiferous material, the steps consisting of passing the material successively through radiant heat zones of increasing temperatures while stirring the material, drawing the hydrocarbon vapors upwardly from the surface of the material and away from the hotter zones where they are formed as fast as they appear and before they enter the hotter zone, and supplying steam to the hotter zone for the formation of ammonia.

10. In the process of distilling solid bituminiferous materials, the steps consisting of

tumbling the materials, applying heat to the material by direct radiation from a heated surface out of contact with the material while said material is being tumbled, and drawing the resulting hydrocarbon vapors at all times away from the material and downwardly away from the heated surface.

11. In the process of distilling solid bituminiferous material, the steps consisting of applying heat to the material by direct radiation from a heated surface out of contact with the material, moving the material to expose different portions thereof to the heat, and drawing the resulting hydrocarbon vapors away from the material and downwardly from the heated surface.

12. In the process of distilling solid bituminiferous material, the steps of tumbling the material, progressively heating the tumbling material to the required temperature in zones of different temperatures by direct radiation only, and drawing off the vapors from cooler portions of the zone of radiant heat at the temperatures at which they are evolved without passing the said vapors through hotter portions of said zone.

Signed at Los Angeles, Calif., this 6th day of August, 1920.

JAY J. JAKOWSKY.