Feb. 20, 1951 V. M. HODGE 2,542,028

APPARATUS FOR HIGH-FREQUENCY RETORTING

Filed Nov. 1, 1946 2 Sheets-Sheet 1

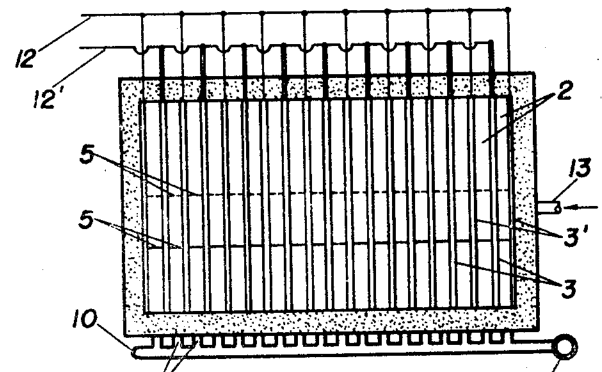

Fig. 3

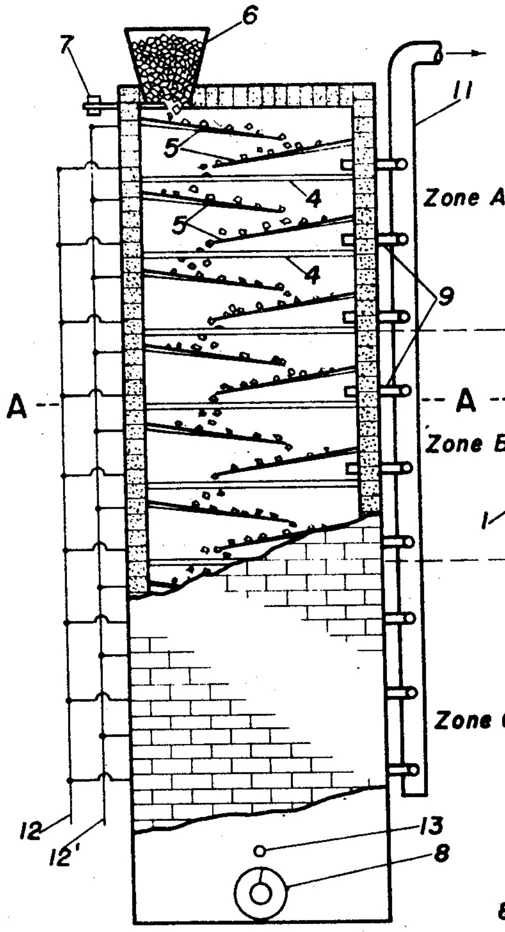

Fig. 1

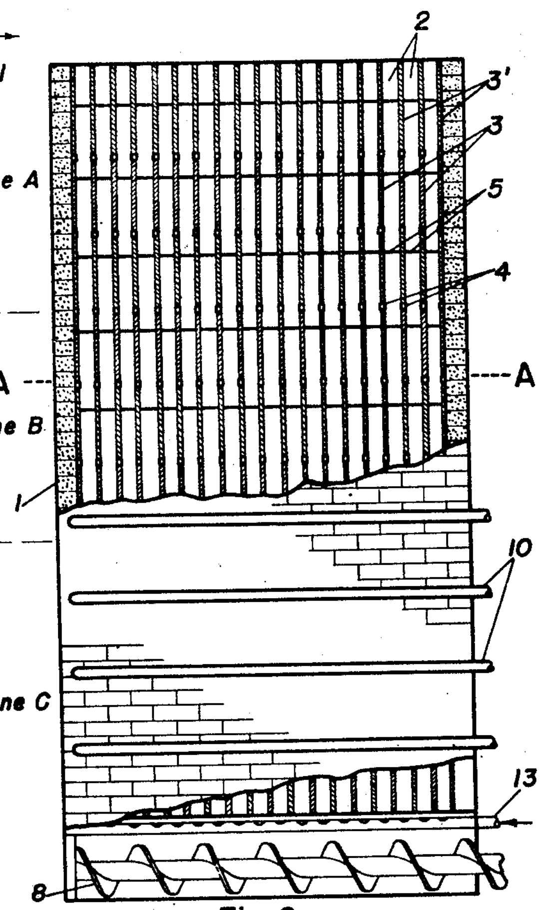

Fig. 2

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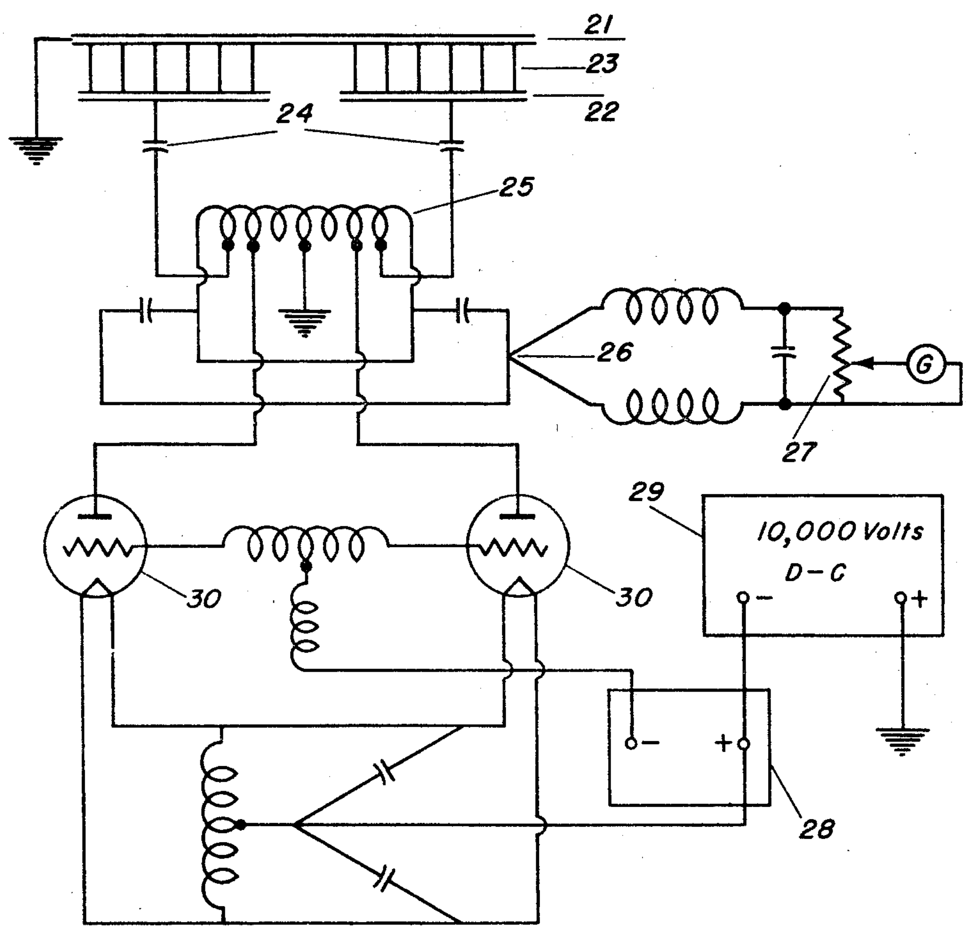

Fig. 4

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UNITED STATES PATENT OFFICE

2,542,028

APPARATUS FOR HIGH-FREQUENCY RETORTING

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Application November 1, 1946, Serial No. 707,119

3 Claims. (Cl. 202—121)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon or therefor.

This invention relates to a method of heating carbonaceous minerals, including low grade coals and carbonaceous shales.

One object of the invention is to provide a novel method of heating carbonaceous minerals by means of a high frequency electrostatic current and to intensify the heating effect on the material.

Another object of the invention is to produce an effective method of heating carbonaceous minerals, whereby their carbon content will be converted to compounds of lower molecular weight and recovered as oils.

Another object of the invention is to provide a method of controlled heating carbonaceous minerals, thereby forming hydrocarbon oils and distilling the hydrocarbon oils in such a way as to minimize decomposition of the formed hydrocarbons during distillation.

Another object of the invention is to provide a method of heating carbonaceous minerals by means of high frequency electrostatic current, applied directly to the carbonaceous mineral, whereby internal heating of the carbonaceous mineral occurs, with the subsequent formation of hydrocarbon compounds, which are distilled by applying additional heat to the residual material and recovering the hydrocarbons.

Another object of the invention is to provide a method of heating carbonaceous minerals by means of high frequency electrostatic current, whereby the carbonaceous content of the mineral is distilled and recovered as hydrocarbon oils and any remaining carbon is converted to a gaseous fuel.

Further objects and advantages will become apparent from the drawing and description, which follows.

The accompanying drawings illustrate one form of apparatus suitable for carrying out the high frequency electrostatic heating of carbonaceous minerals. In the drawings:

Figure 1 is a vertical view, partly in section through one of the narrow retorts.

Figure 2 is a vertical view at right angles to Figure 1, also partly in section, showing the arrangement of retorts and fluid off-take lines.

Figure 3 is a horizontal cross section of the apparatus taken along the line A—A of Figures 1 and 2.

Figure 4 is a diagram of a suitable heating circuit.

As shown in the figures, the device consists of an oven 1 of brick or other suitable refractory construction material containing a series of narrow vertical retorts 2 formed by the metal electrodes 3 separated vertically by the non-metallic spacers 4 and separated horizontally by the non-conducting baffles 5. The material to be processed enters the retorts through the hopper 6, the rate of flow therefrom being controlled by adjustable valve 7, sliding downwardly over the baffles 5 and is removed at the bottom of the retorts by conveyor 8. Gases and vapors generated during the heating flow through off-take pipes 9 and manifolds 10 connected to the downcomer 11, which may be provided with a blower or other suction producing means, not shown, to accelerate flow therethrough, for further processing.

The high frequency current which may be generated in any suitable way, as explained more fully below, is applied to alternate vertical electrodes 3, 3′ through leads 12, 12′, respectively.

The retorts, as explained more fully below, are divided vertically into three zones, A (heating), B (distilling) and C (cooling). The latter zone is cooled by steam admitted through pipe 13. The divisions, it should be understood, have no sharp boundaries, and merely serve to illustrate the successive operations carried out in the high frequency electrostatic heating of the carbonaceous minerals.

Instead of a vertical retort as shown in Figures 1 to 3, inclusive, with gravity flow controlled by the angle and number of baffles 5 and rate of admission of material through valve 7, the retort may be arranged horizontally. In such modification, the material being processed is carried through the several zones by mechanical means such as a travelling grate. The paired electrodes may be spaced vertically on opposite sides of the bed, or suitably insulated plates in the grate could serve as the lower electrode.

Source of heat

The carbonaceous mineral as it passes down between the vertical electrodes 3 is heated by the application thereto of high frequency electrostatic current. This mode of heating should not be confused with high frequency induction heating. In induction heating eddy currents are generated in the metal that is being heated, the eddy currents being dissipated and converted into heat at or near the surface of the metal. On the contrary, high frequency electrostatic heating is the result of internal heating of a material instead of a heating of the surface of the material for conduction through the mass. One explanation of the effect of the high frequency electrostatic heating is that the molecules of the material through which the high frequency is carried are repeatedly changed in shape on applying the electrostatic field to the molecules. The frequency of the current that is applied to the mass determines the number of times the molecule is deformed per second and may be from one to sixty megacycles, according to the nature of the carbonaceous mineral treated and the time of treatment.

Any of the known ways of generating the high frequency electrostatic energy can be used, such as one of the methods of Hartly or Colpitts, which are shown in "The Electronic Engineer's Handbook" by Batcher and Moulic, the Blakiston Company, Philadelphia, Pennsylvania (1944), pp. 373–376.

A satisfactory circuit is shown in Figure 4. In Figure 4, the grounded electrodes are shown by 21, and the electrodes receiving the current by 22. The current reaches these electrodes through coupling capacitors 24, which are in the tank circuit 25. The thermocouple 26 and potentiometer 27 are a part of the watt meter circuit. The high voltage D. C. generator 29 and the variable grid bias 28 supply current to the tubes 30 for producing the high frequency alternating current. The area 23 between electrodes 21 and 22 represents the path of travel of the material being processed in the retort of which electrodes 21 and 22 comprise the heating elements.

Mechanism of heating carbonaceous minerals

The carbonaceous minerals to be treated, including low grade coals and carbonaceous shales, are essentially composed of complex organic compounds with varying percentages of inorganic matter or ash. In general, upon heating such minerals to about 350° C., the complex organic compounds in the carbonaceous part of the mineral begin to decompose forming simpler hydrocarbons principally of the aliphatic and aromatic series. As the temperature of the mineral increases the rate of decomposition of the carbonaceous material in the mineral increases. At the same time the hydrocarbons formed by the decomposition of the corbonaceous part of the mineral begin to distill in the general order of their volatility. Furthermore, as the temperature increases any higher hydrocarbons remaining in contact with the inorganic constituents of the mineral are broken down due in part at least to the catalytic cracking effect of these inorganic constituents of the mineral, particularly the silica and alumina. In order to minimize this cracking effect, it is essential to control closely the temperature of the residual mineral and to remove the hydrocarbons formed as rapidly as possible. The rapid removal of the vapors may be facilitated in this invention by means of suction applied to the retorts through the offtake lines, while over-heating of the residual mineral is avoided by careful control of the applied high frequencies and the time of heating.

Operation of the process

The carbonaceous mineral crushed to flow readily through the hopper and regulating valve, is fed into the hopper, which is maintained full in order to provide an even flow of material to the

retorts. The carbonaceous mineral slides down the baffles in a continuous manner. The high frequency electrostatic current from the generating system is applied to the electrodes, thereby establishing a high frequency electrostatic field between adjacent pairs of electrodes. The extremely rapid reversal of the current preferably in the order of 20 megacycles per second, causes repeated stresses to be set up within the particles of the mineral and the frictional effects result in the generation of heat within the pieces of mineral and a rapid temperature rise thereof.

When the temperature within the pieces of mineral approaches 350° C., the carbonaceous matter begins to decompose. The hydrocarbon oils formed increase the effect of the high frequency electrostatic current and the increased rate of heating results in the vaporization of some of the oils. If desired, a fraction of suitable boiling range may be added to the carbonaceous mineral prior to initial heating in order to increase the rate of initial heating of the mineral.

At this point in the heat treatment of the carbonaceous mineral, it should enter the distillation zone (zone B) where the frequencies and time of heating is arranged to give maximum distillation without overheating the residue, which would result in increasing the catalytic cracking of the formed hydrocarbon oils. In general, the temperature of the mineral residue should not exceed 450° C. in the distillation zone.

From the distillation zone, the solid material passes to the cooling zone (zone C). Steam admitted to this zone through inlet 13 cools the spent mineral and, with any water gas produced by reaction with fixed carbon in the residue, sweeps out any volatile products remaining in the residue. Due to the rapid heating and consequent evolution of volatile products in my method, it may be desirable with the richer shales to admit steam directly to other zones, thereby minimizing secondary cracking and other side reactions.

In spite of the fact that it is desired to cool the spent mineral before it leaves the retorts, it may be necessary to supply a small amount of heat to this zone to take care of the endothermic water gas reaction, particularly if maximum production of water gas is desired. Consequently the frequencies of the applied current and conditions of heating are varied in zone C to suit the heat requirements of this zone.

The water gas produced is sucked out through the gas lines along with the hydrocarbon vapors and may be recovered from the condensers and used as supplementary fuel for the production of the required electrical energy.

Advantages of high frequency electrostatic heating

The conventional retorts for low temperature distillation of carbonaceous minerals are heated in two general ways—either externally or internally. In the externally heated retort the walls consist of heat-resistant and heat-conducting material, which allows the heat to penetrate the retort wall and heat the material adjacent to the walls. However, in the case of solid carbonaceous materials which are not highly heat-conductive the carbonaceous mineral in the middle of the retort is not sufficiently heated while the material adjacent to the retort wall is over-heated. This results in uneven temperature distribution in the mineral to be heated and makes temperature control difficult.

In the internally heated retort hot gases are passed in contact with the mineral, but the volume of gas required and the difficulty of recovering the distilled oils is great. Furthermore, the hot gases only transfer heat to the surface of the solid mineral particles, and since they are poor heat-conductors the outside of the pieces of mineral are hot and the inside relatively cooler. Therefore, any hydrocarbon oils distilling out from the inside pass through a zone of hot mineral which acts as an ideal cracking catalyst and produces cracking of the higher hydrocarbon oils.

According to the present invention, however, the heat is generated inside the individual lumps or particles of mineral and the hydrocarbon oils distill out through a relatively cooler zone at the surface of the particle thereby markedly decreasing the decomposition of the generated hydrocarbons and increasing the yield of primary conversion products.

This has been found to be of particular importance in the distillation of Colorado shales, where it is essential to maintain the temperature of heating within narrow limits so as to decompose the carbonaceous part of the shale and rapidly distill the hydrocarbon oils formed, with the minimum amount of cracking and formation of fixed carbon.

While the apparatus disclosed and described herein constitutes a preferred form of the invention, yet it is understood that the process is capable of substantial alteration without departing from the spirit of the invention, and that all such modifications as fall within the scope of the appended claims are intended to be included therein.

I claim:

1. Apparatus for the destructive distillation of solid carbonaceous minerals comprising a housing of heat insulating material, a plurality of narrow retort elements vertically disposed in said housing and arranged in side-by-side relation one to another, the side walls of each retort element being formed of a plurality of metal plates, non-conducting spacers between the horizontal edges of adjacent plates, a plurality of sloping baffles of non-conducting material in each retort, each baffle being of uniform width and so disposed in the retort as to separate the metal plates forming the opposite sides of the retort and having a slope in excess of the angle of repose of material being processed in the retort, an off-take for fluids from each retort in open communication therewith beneath at least one of said baffles, means in the upper portion of said housing for feeding material to said retorts at a controlled rate, means at the bottom of said housing to discharge residual material therefrom at a controlled rate, and a source of variable high frequency current so connected to the plates forming the side walls of each retort as to produce a high-frequency electrostatic field between said walls for heating material passing through said retort.

2. Apparatus for the destructive distillation of solid carbonaceous minerals comprising a housing of heat insulating material, a plurality of substantially parallel metal walls vertically disposed in said housing and arranged to form a series of relatively narrow retorts in side-by-side relation one to another, each of said walls being formed of a plurality of metal plates separated by horizontal non-conducting elements between said plates, a plurality of sloping baffles of non-conducting material in each retort, each baffle being of uniform width and so disposed in the retort as to separate the metal plates forming the opposite sides of the retort and having a slope in excess of the angle of repose of material being processed in the retort, an off-take for fluids from each retort in open communication therewith beneath at least one of said baffles, means at the top of said retort for feeding material to be processed therein at a controlled rate, means at the bottom of said retort to discharge residual material therefrom at a controlled rate, a source of variable high frequency current and means connecting said current source to the plates of alternate walls to establish a high frequency electrostatic field within each of said retorts whereby material passing through said retorts will be heated during its passage through said fields.

3. Apparatus for the destructive distillation of solid carbonaceous minerals comprising a substantially gas tight housing, a retort element formed of a plurality of metal plates each plate extending horizontally across said housing, non-conducting spacers between the horizontal edges of adjacent plates, a plurality of sloping baffles of non-conducting material in the retort, each baffle being of uniform width and so disposed in said retort as to separate the metal plates forming the opposite sides thereof and having a slope in excess of the angle of repose of material being processed in the retort, an off-take for fluids from said retort in open communication therewith beneath at least one of said baffles, means at the top of said retort for feeding material to be processed therein at a controlled rate, means at the bottom of said retort to discharge residual material therefrom at a controlled rate, and a source of variable high frequency current so connected to the plates forming the side walls of the retort as to produce a high-frequency electrostatic field between said walls for heating material passing through said retort.

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