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METHOD OF AND MEANS FOR CONVERTING COAL

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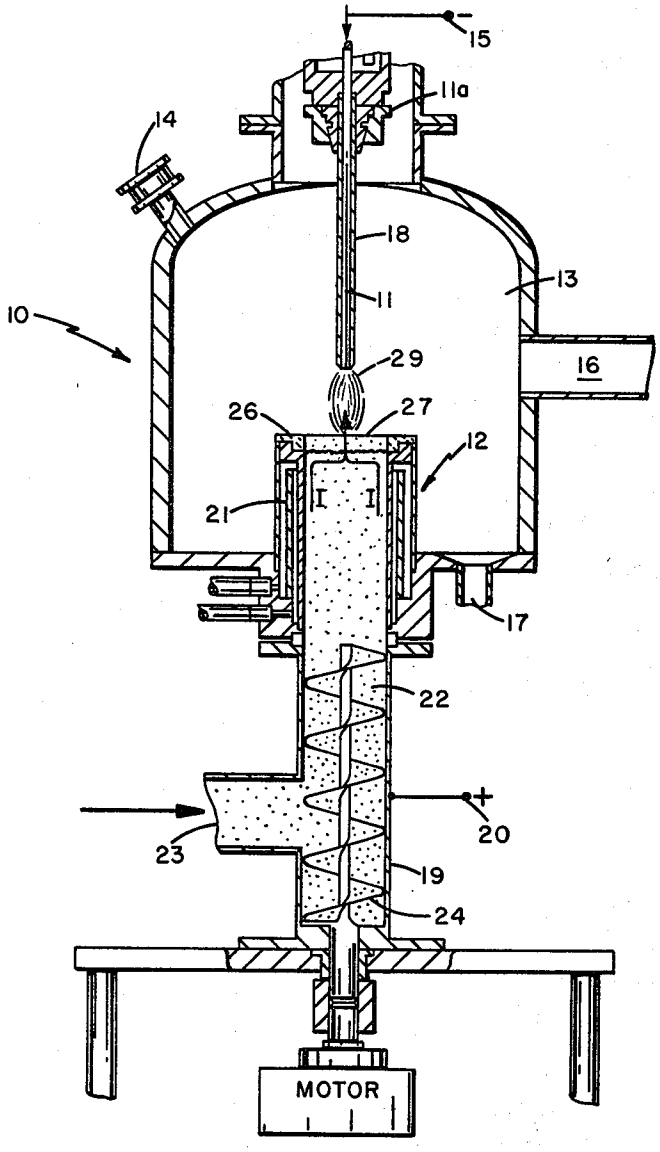


Fig 1

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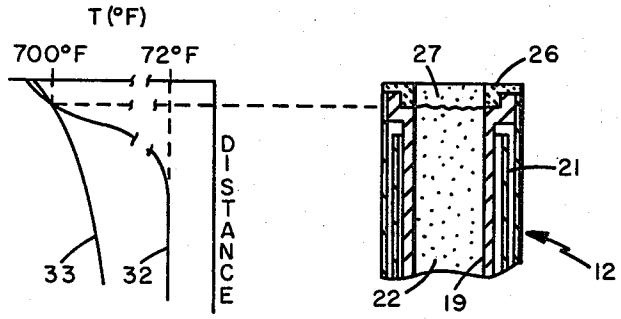


Fig 2

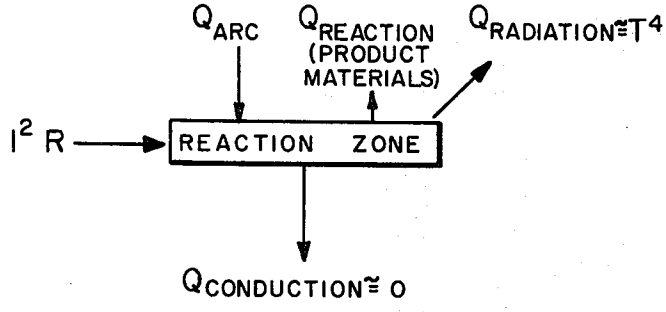


Fig 3

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United States Patent Office 3,384,467 Patented May 21, 1968

3,384,467

METHOD OF AND MEANS FOR CONVERTING COAL

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Filed Feb. 3, 1964, Ser. No. 342,180
8 Claims. (Cl. 48—65)

ABSTRACT OF THE DISCLOSURE

The invention covers a process and means for rapidly decomposing carbonaceous material, coal in particular, into lower molecular weight hydrocarbons. The decomposition is accomplished by causing the carbonaceous material to absorb heat at a rate in the order of several hundred B.t.u.'s/lb.-sec. While the heat could be supplied from any convenient source, an embodiment using an electric arc furnace is preferred and described.

This invention relates generally to processes for converting coal into its lower molecular weight components, and in particular to an electric arc process and apparatus for accomplishing the aforementioned conversion. The meaning of coal as used herein has been broadened to include similar materials such as tar, oil, lignite, charcoal, and coke, for example, all of which could be converted to other fuels and chemical compositions in the manner indicated below.

The structure of a typical bituminous coal has been portrayed graphically in a recent issue of "Industrial Engineering Chemistry," vol. 54, Issue 6 (1962), pp. 36–39, by Hill and Lyon. The structure is exceedingly complex and contains a large proportion of aliphatic chains in which the H/C ratio is 2:1 and a relatively small fraction of polynuclear aromatics (in which the H/C ratio is less than 1). In contrast, anthracite coals also comprise a complex structure but have a small fraction of aliphatic groups and a large fraction of polynuclear aromatics.

In general, the pyrolysis of coal is accomplished through two basic competing reactions, decomposition and polymerization. However, it is recognized that many complex chemical reactions take place during coal pyrolysis.

Of the methods used to convert coal, coking is perhaps the most widely known and used process. During the course of a coking operation, the temperature of coal is raised to a temperature of 700° F. to 2000° F. over an extremely long time. The weakest bonds rupture first. With increasing temperature, successively stronger bonds begin to rupture, but resonance-stabilized carbon-carbon bonds in aromatic rings are apparently preserved. In other words, the basic carbon structure is preserved, and only the groups attached to the carbon structure are driven off. These groups, for example, usually comprise oxygen, hydrogen, and some sulfur and nitrogen. The rate at which heat energy is absorbed in a typical coking operation is in the order of 2.0 B.t.u./lb.-sec.

Coal has also been converted by injecting extremely fine particles of coal, powders, into a plasma generating device. In this process, the coal is heated by the extremely high temperature plasma generated in the plasma generating device. The residence time of the coal powders within the plasma stream is extremely short, in the order of a millisecond or less, and therefore the heat energy entering the particles is also relatively small, and the extent of conversion is small. The reaction rate is of the order of one million B.t.u./lb.-sec. In spite of the high

rate, the thermal efficiency of the process is only of the order of a few percent.

Attempts have also been made to convert coal by other arc techniques. In general, these processes have not produced satisfactory yields of low molecular weight fuels and chemicals.

It is an object of the invention to provide means for and method of converting coal which avoids the limitations and disadvantages of the prior are processes.

It is another object of the invention to provide a coal conversion process wherein the coal is converted to low molecular weight hydrocarbon gases such as methane and typically unsaturated products such as ethylene and acetylene.

It is yet another object of the invention to provide a process for converting coal wherein heat energy is supplied to the coal at an extremely high rate and with high electrical efficiency.

It is still another object of the invention to provide a coal conversion process wherein the high energy bonds are ruptured.

It is still another object of the invention to provide an efficient electric arc apparatus for converting coal.

It is yet another object of the invention to provide an electric arc apparatus for converting coal wherein the coal becomes an active apparatus structure.

It is yet another object of the invention to provide an electric arc apparatus for converting coal wherein the rate at which heat energy is absorbed in the coal is high, efficient and controllable in a simple and facile manner.

In accordance with the invention, a method of converting coal comprises absorption of heat energy in the coal at a rate greatly exceeding the heat transfer rate typically used in coking. The heat transfer rate encountered in performing this process is typically 600 to 1,000 B.t.u./lb.-sec. or greater.

Another aspect of the invention is an electric arc furnace for converting coal which comprises at least two spaced electrodes. One of the electrodes is a sleeve having a central passage. The end of the sleeve to which an arc is struck (the arc end) is terminated with an electrical insulator. The arc furnace also includes means for supplying coal to said central passage and for conveying the coal to the arc end of the sleeve.

The novel features that are considered characteristic of the invention are set forth in the appended claims; the invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic representation of an electric arc apparatus useful for converting coal and which embodies the principles of the present invention;

FIGURE 2 includes a schematic representation of the anode electrode of the FIGURE 1 apparatus and a curve useful in explaining the operation of the invention;

FIGURE 3 shows a heat energy utilization diagram.

In FIGURE 1 there is shown a schematic representation of an electric arc coal converting apparatus generally designated **10**. It includes a pair of spaced electrodes **11** and **12** connected to means for supplying electrical power **15** and **20**, respectively, and a reaction chamber **13**.

The reaction chamber **13** is a sealed container which includes a sight glass **14** and exit port **16** for gas products produced therein and a withdrawal pipe **17** for removing solid residue, resulting from the coal conversion process, from the reaction chamber.

The electrode **11** is a graphite rod which is held in a water-cooled holder **11***a* and containing a central passage

18. Electrode 11 acts as a cathode electrode. Electrode 12, the anode electrode, comprises a sleeve 19 including a water-cooled jacket 21 at its upper end and a central passage 22. The passage 22 is preferably completely filled with coal particles supplied thereto through an entrance port 23 in one side of the sleeve 19 and propelled upward through the passage 22 by a continuously rotating screw feed mechanism 24. A cap 26 formed from any suitable refractory electrical insulating material such as alumina covers the arc end of the sleeve 19 opposite the cathode 11. The number 27 denotes a reaction zone in which substantially all of the coal conversion takes place. The electric arc is identified by the numeral 29.

As is well known, coal, whether it is bituminous or anthracite coal, is at best an extremely poor conductor of electricity at ambient room temperatures, about 72° F. It is also well known that when coal is charred or heated to a temperature at which incipient fusion is noticed, it becomes a good conductor of electricity. There is a direct relationship between temperature and conduction above the fusion point.

Pulverized coal is fed through the entrance port 23 to the passage 22 where it is advanced by the screw feed 24 to the reaction zone 27. When the passage 22 is filled with coal, electrical power is supplied to strike and maintain an arc between the cathode 11 and the anode 12.

Since electrical current cannot flow from cathode 11 to the sleeve 19 because of the insulating cap 26, the coal within the reaction zone 27 must be heated to improve its conductivity to a point where it is capable of carrying the arc current. The reaction zone 27 may be heated initially by coating its surface with a char and striking an arc to the char in a conventional fashion. Thereafter, the arc is sustained by the electrical current and the continuous reaction of the coal in the reaction zone 27.

Referring to FIGURE 2 of the drawings, there is an enlarged, partly schematic representation of the arc end of the anode 12. It is seen that the reaction zone 27 is limited to a small volume at the extremity of the anode 12. The curve 32 portrays the temperature distribution within the anode 12 as a function of the distance from the exposed surface of the reaction zone 27, for the case of rapid feeding of the coal. The slope of the curve 32 is a function of the coal feed rate velocity. It will be seen that the temperature drops off extremely rapidly immediately behind the reaction zone 27. There is a slight temperature gradient within the reaction zone 27 probably due to the heat energy being absorbed in the chemical reactions taking place therein.

FIGURE 3 is an energy utilization chart. The heat energy applied to the reaction zone 27 is derived principally from the arc and particularly by the striking by high energy electrons at the surface, with a small contribution from the I^2R losses generated by the current passing through the reaction zone 27. The heat losses occur from conduction through the anode which is substantially zero for even modest coal feed velocities, from radiation which amounts to about 4 percent. The heat of reaction accounts for about 96 percent.

The parameters effect a conversion of the coal and, manifestly, the power supplied to the reaction zone 27 by the arc and the rate at which coal is supplied to the reaction zone 27. Since the temperature of the reaction zone 27 ranges from 700° F. to about 2000° F., the heat energy loss through heat radiation remains substantially small, even as the power and the coal supply rate are varied. The latter is varied by controlling the rotational speed of the screw feed 24.

Important considerations, therefore, are the heat absorption rate, which for the purposes of this discussion is defined as the B.t.u.'s per pound of coal per second (B.t.u/lb.-sec.) and the efficiency with which the energy is used for coal conversion.

Whereas essentially all of the heat supplied to a coking bin is utilized, the heat absorption rate is very low. In

plasma devices the heat absorption rate is very high, but the efficiency with which the energy in plasma is used to convert coal is very low.

In contrast to both coking and plasma generator conversion, the heat absorbed by the reaction zone 27 is efficiently utilized, at least 50 percent for high loss apparatus and at least 85 percent for an average electric arc furnace. Additionally, the heat absorption rate exceeds that of coking by at least two orders of magnitude.

Whereas the substantially slow pyrolysis process of coking results predominantly in polymerization of the coal and the retention of a solid carbonized substance, higher heat absorption rates such as are experienced through the practice of the above-described process shock the coal into decomposing, with a substantial severance of the high energy basic bond structure, and particularly the carbon bonds and the consequential production of low molecular weight products. Heat energy absorption rates as low as 200 B.t.u./lb.-sec. would result in substantial decomposition products and a lesser proportion of polymerization products. The preferential heat energy absorption rates for low and high volatile coals lie in the range of 600 to 1,000 B.t.u./lb.-sec. Heat utilization efficiencies range from 50 to 96 percent.

Interpreted in another way, conversion of coal by decomposition results when coal is brought to a temperature of at least 700° F. and vaporized within several seconds; the time element is commonly referred to as the residence time and these are typically 18 seconds for 200 B.t.u./lb.-sec. and 3 and 6 seconds for 600 to 1,000 B.t.u./lb.-sec. respectively. Data relating to a typical conversion process is provided in Table I below:

Table I

Coal analysis (wt. percent):	
C	82.5
H	5.71
O	6.27
N	0
S	1.0
Ash	4.48
Product gas (mole percent):	
H_2	72.34
CO	8.37
CH_4	9.42
C_2H_6	0.95
CO_2	2.40
C_2H_4	1.46
C_2H_2	5.06
Absorption rate ——B.t.u./lb.sec.—	600
Heat utilization efficiency ——percent—	96
Anode diameter ——inches—	2
Reaction zone depth ——inch—	¼
Residence time ——seconds—	3

In the foregoing, the gas products were estimated to be 15 percent (by weight of the initial coal). Theoretically, with this composition a 30 percent conversion should be possible, assuming all of the original hydrogen appears in the gas phase.

Experience has shown that the proportions of low molecular weight products produced will vary if the coal feed rate and the energy supply per unit of coal fed is varied. Additionally, the structure of the reaction chamber 13 also affects these proportions. For example, unless the gas products are removed immediately after they are produced, there is a tendency for a portion of these products to come in contact again with the arc and undergo further conversion. Generally, this second conversion results in products which are thermodynamically more stable at high temperatures since additional heat energy is supplied to the initial reaction products by the arc during the second or subsequent passage of these initial products through the arc.

Additionally, it is possible to recirculate reaction products through the arc or introduce additional reactive agents to mix with and react with the reaction products through passage **18** in cathode **11**.

Given a specific arc furnace, the coal feed rate and electric arc power may be adjusted to optimize the production of a particular reaction product. By performing an instantaneous analysis of the reaction products and utilizing automatic processing equipment to adjust the electric power and coal feed rate, it is possible to adjust the production of a particular reaction product.

The various features and advantages of the invention are thought to be clear from the foregoing description. Various other features and advantages not specifically enumerated will undoubtedly occur to those versed in the art, as likewise will many variations and modifications of the preferred embodiment illustrated—particularly in relation to the broad definition of coal used herein—all of which may be achieved without departing from the spirit and scope of the invention as defined by the following claims.

We claim:

1. A method of converting coal to lower molecular weight hydrocarbons in an electric arc furnace having at least two spaced electrodes, one of said electrodes having electrically insulated surfaces facing said other electrode, comprising:

(a) utilizing coal to form at least a portion of said one electrode wherein said coal forms an exposed surface opposing said other electrode;

(b) heating said exposed surface of said coal electrode opposing said other electrode and a reaction zone immediately behind said surface to substantially increase the electrical conductivity of said surface and reaction zone;

(c) striking and maintaining an arc and terminating said arc on said exposed surface for supplying heat energy to said coal for gasifying substantially all of said surface and reaction zone; and

(d) replenishing coal gasified from said surface and reaction zone at a rate commensurate with the gasification rate.

2. An electric arc furnace for converting coal to lower molecular weight hydrocarbons comprising:

(a) at least two spaced electrodes, one of said electrodes being a sleeve having a central passage, the arc end of said sleeve being terminated with an electrical insulator;

(b) means for feeding coal to said central passage for supplying said arc end with coal;

(c) means coupled to said electrodes for supplying electrical current to an arc struck between said electrodes; and

(d) means for removing conversion product from the furnace.

3. An apparatus as described in claim **2** in which said electrical insulator is a refractory ceramic material.

4. A process for converting coal to lower molecular weight hydrocarbons in an electric arc furnace comprising:

(a) utilizing coal to form at least a portion of one electrode wherein said coal forms an exposed surface opposing said other electrode;

(b) heating a reaction zone of coal behind said exposed surface to at least 700° F.;

(c) striking a high intensity arc and terminating one end of said arc on said reaction zone for maintaining said reaction zone at at least 700° F. for thermally converting said coal into lower molecular weight components; and

(d) feeding coal to said reaction zone to replenish converted coal, said arc intensity and coal feed rate being adjusted such that the coal in the reaction zone absorbs heat at the rate of 200 to 1000 B.t.u.'s/lb.-sec.

5. A method of converting coal to lower molecular weight hydrocarbons comprising supplying heat to said coal under conditions whereby the coal absorbs heat at the rate of in the order of 200 to 1000 B.t.u.'s/lb.-sec. to decompose said coal.

6. A method of converting coal to lower molecular weight hydrocarbons as described in claim **5** wherein the coal absorbs heat at the rate of 600 to 1000 B.t.u.'s/lb.-sec.

7. A method of converting coal to lower molecular weight hydrocarbons in an electric arc furnace having at least two spaced electrodes comprising:

(a) utilizing coal to form at least a portion of one electrode wherein said coal forms an exposed surface opposing said other electrode;

(b) heating said exposed surface of said coal electrode opposing said other electrode and a reaction zone immediately behind said surface to substantially increase the electrical conductivity of said surface and reaction zone;

(c) striking and maintaining an arc to said surface for supplying heat energy to said coal so that said coal absorbs the heat energy at a rate in the order of magnitude of 200 B.t.u.'s/lb.-sec. to 1000 B.t.u.'s/lb.-sec.; and

(d) replenishing coal gasified from said surface and reaction zone at a rate commensurate with the gasification rate.

8. A method as described in claim **7** in which said heat energy absorption is in the range of 600 to 1000 B.t.u./lb.-sec.

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