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CARBONIZATION OF COAL IN A FLUIDIZED BED

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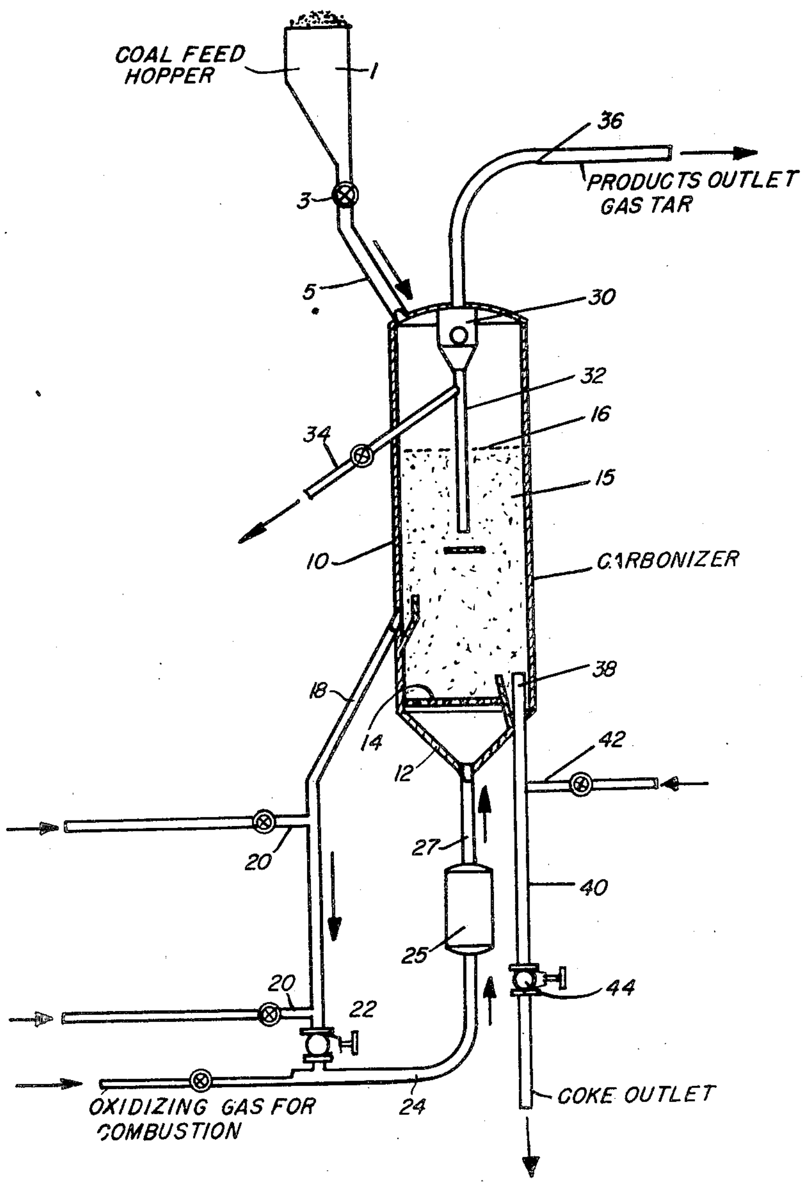

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CARBONIZATION OF COAL IN A FLUIDIZED BED

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The present invention relates to the carbonization of carbonaceous fuels such as all types of coal, lignite, cellulosic materials including lignin, oil shale, tar sands, as well as heavy oil residues, asphalts and the like to produce carbonized solids, gas and valuable volatile materials. More particularly, the invention is concerned with improved means for the carbonization of these fuels in a dense turbulent bed of finely divided solids fluidized by an upwardly streaming gas.

The application of the so-called fluid solids technique to the carbonization of solid carbonizable fuels is well known in the art. In this process, finely divided carbonizable solids such as coal, having a fluidizable particle size of say about 40–400 mesh, are fed to a carbonizer wherein they are maintained at carbonization temperature in the form of a dense turbulent fluidized bed of finely divided solids forming a well defined upper level. A gas is blown upwardly through the bed to cause, in cooperation with the vaporous carbonization products, the desired fluidization of the mass.

This technique is greatly superior to conventional fixed bed operation. It provides larger solid reaction surfaces, better mixing, greatly improved temperature control, it affords higher yields of valuable volatile carbonization products, it produces a more uniform higher quality coke and it makes possible carbonization at a predetermined temperature in much less time than in ordinary by-product coking practice.

While these great advantages make the application of the fluid solids technique to coal carbonization appear highly attractive, it has not as yet found the broad commercial application it would seem to deserve. One of the more important reasons for the slowness of this development lies in difficulties encountered in connection with the heat supply to the carbonizer bed. Several different principles have been suggested and actually tested for this purpose.

One principle involves direct or indirect heating of the carbonizer bed by the sensible heat of preheated gases such as steam, make gas, flue gas, etc. The heat capacity of these gases is so low that either excessively large quantities of heating gas have to be supplied or the temperature difference between the heating gas and the carbonizer bed must be very great. In either case, the fuel consumption in the extraneous heating equipment required to preheat or produce the heating gas is disproportionately large. Moreover, the temperatures in that extraneous equipment are required to be so much higher than the carbonization temperature that the utility of this procedure is seriously limited by the effect of heat on economical construction materials.

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Another principle involves the direct or indirect heating of the carbonizer bed by means of the sensible heat of a heat carrying finely divided solid heated in a separate heater. This method requires the circulation of very large amounts of heat transfer solids at low temperature differentials. If smaller amounts of heat transfer solids at large temperature differentials are circulated the quality of the coke is affected detrimentally by exposure to the high heater temperatures. In addition, gas-solids separating equipment must be provided for both the carbonizer and the heater vessels.

The third principle utilizes the heat generated within the carbonizer bed by a partial combustion which is supported by an oxidizing gas such as air and/or oxygen blown through the bed in suitable amounts. This method suffers a severe penalty since the air and/or oxygen admitted for combustion burns appreciable portions of the most valuable volatile carbonization products. The losses sustained in this manner may amount, in many cases, to as much as 20–50% of the volatile products. In many cases these losses of volatile carbonization products render the process uneconomical.

The present invention overcomes the aforementioned difficulties and affords various additional advantages, as will be fully understood from the following detailed description read with reference to the accompanying drawing.

It is, therefore, the main object of the present invention to provide improved means for the carbonization of carbonizable fuels employing the fluid solids technique.

A more specific object of the present invention is to provide improved means for supplying heat to a carbonization zone employing the fluid solids technique.

Other and further objects and advantages will become apparent from the following disclosure and claims.

We have found that these objects and advantages may be accomplished by providing an external combustion zone wherein coke from the carbonizer is burned, preferably in a fluidized state, with an oxidizing gas at conditions permitting the generation of the heat required in the carbonization zone and a substantially complete consumption of the oxygen supplied to the combustion zone. The heat so generated in the combustion zone is transferred to the carbonization zone as sensible heat of the flue gases produced in the combustion zone and, preferably as sensible heat of flue gases and suspended particles of solid combustion residue from the combustion zone.

In this manner we combine the advantages of the heating principles outlined above while either eliminating or substantially diminishing their disadvantages. More particularly, the merits of direct heating by internal partial combustion are fully realized without the destruction of desirable volatile products, without excessive solids circulation and without the need for excessive temperatures in the external heating equipment.

In accordance with the preferred embodiment of our invention, finely divided coke is withdrawn from the fluid carbonization bed, stripped with a stripping gas to remove valuable volatile carbonization products and suspended in combustion-supporting gas such as air and/or oxygen sufficient in amount to support the desired combustion. The suspension of coke in an oxidizing gas is passed upwardly through a combustion zone which is so designed and operated that complete consumption of the oxygen admitted thereto is accomplished while the desired amount of heat is generated. Hot flue gases and suspended solids are directly passed to the bottom of the carbonization bed. The heat generated in the combustion zone is a function of the oxygen consumed. The combustion space should be large enough and the temperature of combustion high enough so that the rate of combustion is limited or controlled solely by the feed rate of oxidizing gas to the combustion zone. At constant feed rates of oxidizing gas to the combustion zone and, therefore, of flue gas to the carbonization zone the temperature of the combustion zone may, therefore, be controlled by varying the supply of coke from the carbonizer and the fresh feed of carbonizable material to the carbonization zone. It will be understood that the heat-carrying flue gas from the combustion zone may be used to fluidize the carbonization bed.

If desired, the combustion zone may be operated as a true upflow reactor, that is, at a relatively high superficial velocity of oxidizing gas so that the total solid combustion residue and its sensible heat is transferred to the carbonizer. The carbonizer may be operated either as an upflow or downflow reactor, that is, the carbonized solids may either be withdrawn completely overhead together with the volatile carbonization products or most of the solids may be withdrawn downwardly from the fluidized bed separate from the volatile products. In the first case the cross sections of the carbonizer and combustion zone may be substantially the same, while in the second case the cross section of the combustion zone may be substantially smaller than that of the carbonizer in order to reduce the superficial gas velocity in the carbonizer.

Having set forth the general nature and objects, the invention will be best understood from the more detailed description hereinafter in which reference will be made to the accompanying drawing which shows a semi-diagrammatic view of a system suitable for carrying out a preferred modification of the present invention.

Referring now in detail to the drawing, the numeral 10 designates the carbonizer or coker which is in the form of a cylindrical vessel fitted with a conical base 12 separated from the cylindrical section by a distributing grid 14. The finely divided solid carbonizable fuel such as carbonization coal is supplied from feed hopper 1 by a conventional feeding mechanism such as a star feeder 3 through line 5 to carbonizer 10. The finely divided material should have a particle size of the order of below 50 mesh or even less than 100 mesh although even smaller sizes or lumps up to ¼ in. or ½ in. size may be used. The mass of finely divided carbonaceous material in carbonizer 10 is maintained at carbonization temperature and in the fluidized state to form a fluidized bed 15 having a well defined upper level 16, as will appear more clearly hereinafter.

A finely divided solid carbonization product such as coke is withdrawn downwardly from bed 15 through standpipe 18 provided with aerating taps 20. In place of standpipe 18 any other conveying means suitable for conveying finely divided solids such as mechanical conveyors, etc., may be used. An inert gas such as steam or flue gas may be injected through taps 20 in amounts sufficient to facilitate the flow of solids through standpipe 18 and simultaneously to strip the solids of adhering volatile carbonization products.

Standpipe 18 is provided with a slide valve 22 which controls the flow of solids into gas supply line 24 carrying an oxidizing gas such as air and/or oxygen. The suspension of coke and oxidizing gas is passed to the bottom of combustion zone 25 wherein combustion of coke takes place at a rate sufficient to consume all oxygen available in zone 25 and to generate the heat required for carbonization. The oxidizing gas may be preheated, for instance, in heat exchange with volatile carbonization products to a temperature of about 500° to 700° F. or higher while the coke is supplied substantially at the temperature of bed 15 which may fall within the wide range of about 800° to 2000° F.

The design and operating conditions of combustion zone 25 depend on the heat requirements of carbonizer 10, that is, on the character of the carbonaceous feed as well as on the amount of carbonaceous feed to be carbonized per unit of time and the desired carbonization temperature. For example, in order to maintain a carbonization temperature of about 850° F. while feeding bituminous coal containing 5% moisture, an upflow combustion zone may be operated at a temperature of about 900°–1600° F., superficial gas velocities of 0.3 to 20 ft. per second and a coke circulation rate of 1 to 20 lbs., an air feed rate of about 0.35 lb. of air at 150° F. and a combustion space of 0.002 to 0.03 cu. ft. per lb. of carbonaceous solids to be carbonized per hour. It should be noted, however, that these ranges will change as the carbonization temperature and/or the character of the carbonizable charge are varied as will be understood by those skilled in the art.

Hot flue gases containing substantial amounts of suspended solid combustion residue are passed substantially at the temperature of combustion zone 25 which may range anywhere from about 900° to 2000° F. depending on the specific conditions involved, through line 27 to the conical bottom portion 12 of carbonizer 10 and from there through distributing grid 14 into carbonization bed 15. The hot combustion products transfer their heat to the carbonaceous feed in bed 15 to maintain it at carbonization temperature. The flue gases whose superficial velocity has been reduced by the enlarged cross section of carbonizer 10 to about 0.3 to 3 ft. per second maintain carbonization bed 15 in the form of a dense turbulent fluidized mass of carbonaceous solids undergoing carbonization.

Volatile carbonization products such as coal gas, tar vapors, etc., containing fines of carbonaceous material are withdrawn overhead from bed 15 and passed through a conventional gas solids separator, such as cyclone separator 30 and may be returned through line 32 to bed 15 or discarded through line 34. Gases and vapors substantially free of solids are withdrawn through line 36 and passed to a conventional product recovery system (not shown), if desired after heat exchange with the oxidizing gas supplied to combustion zone 25.

Carbonized product or coke is withdrawn through bottom drawoff 38 and standpipe 40 for recovery or further treatment such as briquetting, etc. Standpipe 40 is provided with one or more aeration taps 42 and a slide valve 44 which controls the rate of coke withdrawal from carbonizer 10.

As previously indicated, the temperature of combustion zone 25 and carbonization bed 15 may be readily controlled at a constant supply of oxidizing gas through line 24 by properly manipulating valves 22 and 44 and star feeder 3. This can be done by means of automatic control instruments. For example, at a controlled constant supply of oxidizing gas through line 24, the temperature of combustion zone 25 may be controlled by controlling the coke circulation rate to zone 25 with the aid of slide valve 22. Additionally the temperature in the carbonization zone may be independently controlled as a function of the feed rate of fresh carbonaceous charge governed by the rotation of star feeder 3 and the controlled withdrawal of char through valve 44 so as to maintain level 16 constant.

The combustion zone 25 is shown in the drawing as a separate vessel located in the carbonizer inlet transfer line, the vessel being so dimensioned as to allow complete utilization of the oxygen admitted. It will be understood, however, that the transfer line itself, that is line 24, may, if properly dimensioned, serve as the combustion zone. Regardless of the specific form of the equipment it should be so designed as to afford complete consumption of the oxygen in the gas entering through line 24 and to permit the combustion of sufficient coke to supply the total heat required for carbonization.

Our invention will be further illustrated by the following specific example which demonstrates the advantage of our invention over heat supply by partial combustion within the carbonizer itself.

Example

The carbonization of a bituminous coal at a temperature of about 900° F. in a carbonizer employing the fluid solids technique produces the yields listed below for the case of air being admitted directly to the carbonizer and the case of heat being generated in an external combustion zone in accordance with the present invention.

Product Lbs./100 Lbs. of Raw Coal	Air Admitted Directly to Carbonizer	Air Admitted to External Combustion Zone
Coke	72.9	69.7
Light Oils	0.6	0.8
Dry Gas	40.9	42.6
Tar	7.3	10.0
Liquor+Loss	15.7	14.3

It will be noted that the application of the external combustion zone, in accordance with the present invention, involves combustion of coke to the extent of about 3% by weight of coal fed to the carbonizer. On the other hand, where the air required for combustion is injected directly to the carbonizer vessel, the combustion of product tar reduces the yield of this most valuable by product by about 20 to 50%.

In comparison with conventional separate heater design, the increase in tar yield obtained by the process of the invention will be less significant. However, the quality of the coke, for instance, its steam and/or oxidizing reactivity produced in accordance with the present invention is greatly superior because the heater may be operated at a lower temperature.

While air and oxygen have been mentioned as equivalent oxidizing gases, it will be understood by those skilled in the art, that oxygen or gases rich in oxygen should be used in cases in which volatile products of high calorific value and low inert gas content are desired. An auxiliary fluidizing gas such as steam or the like, may be introduced preferably into the conical bottom section 12 of carbonizer 10 if the flue gas produced in combustion zone 25 should be insufficient to accomplish proper fluidization of carbonizer bed 15. Our process may be operated at atmospheric or elevated pressures ranging up to about 400 lbs. per sq. in. or higher, pressures of about atmospheric to 200 lbs. per sq. in. being preferred. It will also be appreciated that the system illustrated by the drawing may be operated fully continuously by continuously feeding carbonaceous charge from feed hopper 1, continuously circulating coke through line 18, and continuously withdrawing solid and volatile products through lines 40 and 36 respectively.

In the foregoing description of our invention we have mainly referred to the use of solid carbonaceous fuels as a suitable charge to carbonizer 10. It is noted, however, that carbonaceous fuels, liquid at the carbonization conditions, such as crude oil, heavy petroleum residues, asphalt, or the like may also be used. In this case, a solid finely divided carrier material such as coke, sand, or the like is maintained at carbonization conditions in the form of a fluidized bed in carbonizer 10 and the liquid carbonaceous charge is deposited and carbonized on the fluidized carrier material substantially as described above.

The foregoing description and exemplary operations have served to illustrate specific applications and results of our invention. However, other modifications obvious to those skilled in the art are within the scope of our invention. Only such limitations should be imposed on the invention as are indicated in the appended claims.

We claim:

1. A method for carbonizing coal which comprises maintaining a dense, turbulent, fluidized bed of finely divided solids at carbonizing conditions including a temperature suitable for low temperature carbonization of the order of 800°–900° F. in a carbonization zone, feeding finely divided coal to said bed, passing a gas upwardly through said bed at a rate sufficient to maintain it in a fluidized condition while forming a well defined upper level, withdrawing finely divided product coke downwardly from said bed, suspending said withdrawn product coke in an oxidizing gas rich in free oxygen, passing the suspension

formed in light phase upflow fashion upwardly through a combustion zone at a temperature of about 900°–1600° F. but higher than said carbonization temperature, completely reacting in said combustion zone all the oxygen available in said combustion zone while leaving unburned carbon on said coke, thereby generating sufficient heat by combustion to support said carbonization, passing gases and entrained solids overhead from said combustion zone substantially at the temperature of said combustion zone directly and upwardly into a lower portion of said bed, supplying all the heat required for the carbonization in the form of the sensible heat of said gases and entrained solids passed overhead from said combustion zone, withdrawing volatile carbonization products overhead from said level and withdrawing a separate stream of product coke downwardly from said bed.

2. The process of claim 1 wherein the temperature of said combustion zone is controlled by maintaining a constant feed rate of oxidizing gas and varying the circulation rate of product coke to said combustion zone.

3. The process of claim 1 wherein the superficial gas velocity in said combustion zone is substantially greater than the superficial gas velocity in said carbonization zone.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,899,887	Thiele	Feb. 28, 1933
1,984,380	Odell	Dec. 18, 1934
2,277,070	Carney	Mar. 24, 1942
2,356,717	Williams	Aug. 22, 1944
2,377,657	Watts	June 5, 1945
2,414,586	Egloff	Jan. 21, 1947
2,432,135	Barr	Dec. 9, 1947

FOREIGN PATENTS

Number	Country	Date
286,404	Great Britain	Mar. 8, 1928
335,740	Great Britain	Oct. 2, 1930
578,711	Great Britain	July 9, 1946