

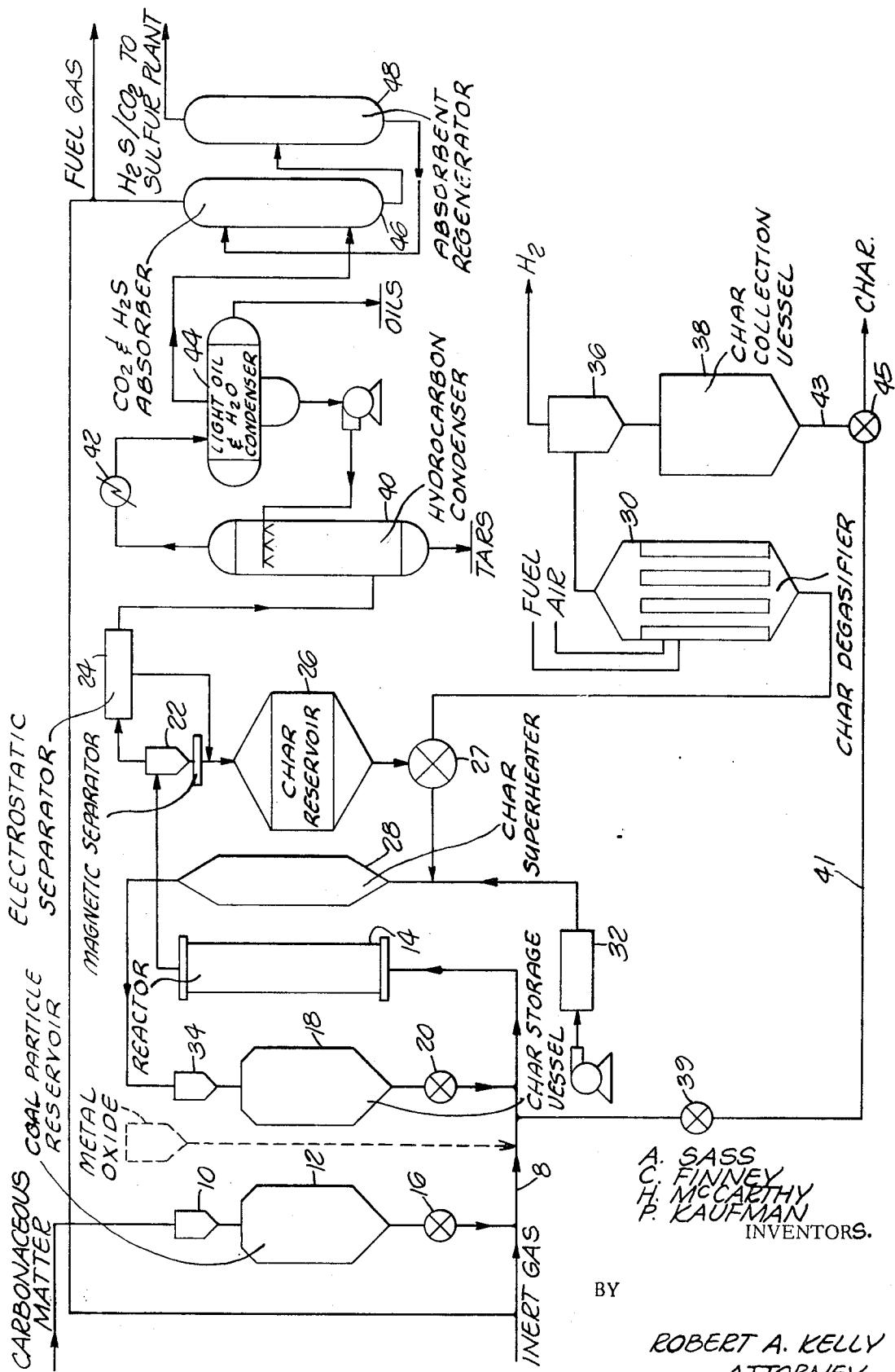
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PROCESS OF PYROLYZING AND DESULFURIZING SULFUR
BEARING AGGLOMERATIVE BITUMINOUS COAL

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PROCESS OF PYROLYZING AND DESULFURIZING SULFUR BEARING AGGLOMERATIVE BITUMINOUS COAL

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ABSTRACT OF THE DISCLOSURE

This invention discloses an efficient economical continuous method of pyrolyzing and desulfurizing agglomerative bituminous coal in a transport reactor to recover volatile hydrocarbons and hydrogen by heating the particulate coal and char having particle sizes of less than 65 microns entrained in an inert carrier gas having pyrolysis reactor residence times of under three seconds.

BACKGROUND OF INVENTION

The use of fluidized systems wherein a fluidized stream is formed of finely divided coal particles, heated char particles and a carrier stream to pyrolyze the coal particles to extract the volatiles therefrom is well known in the art. In such prior art processes the heated char particles and/or the gas stream are utilized to provide the requisite heat of pyrolysis to the coal particles with a supply of char continuously being produced upon pyrolysis of the coal in the system. Such systems are ideally suited to the recovery of volatiles from agglomerative bituminous coal, since they are continuous processes, requiring relatively low capital outlays and can process large volumes of coal cheaply. Exemplary of such type processes is that disclosed in the U.S. Pat. No. 2,608,526 entitled "Coking of Carbonaceous Fuels" issued to W. A. Rex on Aug. 26, 1952.

However, when such prior art processes have been applied to agglomerative bituminous coal, problems have arisen due to the agglomerative nature of such coal. The agglomeration of the coal particles causes severe blockages in the system and renders the system inoperable. In recognition of the severity of this problem, the inventors in the U.S. Pats. 2,955,077 entitled "Fluidized Carbonization Process for Agglomerative Coals" issued to J. H. Welinsky, Oct. 4, 1960 and 3,375,175 entitled "Pyrolysis of Coal" issued to R. T. Eddinger, Mar. 26, 1968 disclose the use of a pretreatment of particulate agglomerative coal to lessen the deleterious effects of agglomeration. In these processes the agglomerative particulate coal is preheated in a conventional fluidized bed at temperatures ranging from 600° F. to 825° F. for periods ranging from 1 to 30 minutes to remove at least a portion of the volatiles from the coal so that the coal can be further pyrolyzed to recover the volatiles therefrom. The requirement of preheating agglomerative bituminous coals in these processes for relatively long residence times imposes severe economic limitations on these processes.

SUMMARY OF INVENTION

This invention discloses a continuous process for the pyrolysis of agglomerative bituminous coal to recover the volatiles therefrom comprising forming a high velocity stream composed of particulate agglomerative coal, particulate char and a substantially inert carrier gas in a pyrolysis zone, such that the char and coal particles are intimately admixed and entrained within the gaseous portion of the stream, the solids content of said stream in

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the zone ranging from about 0.1 to about 10.0 percent by volume based upon the total volume of the stream in the pyrolysis zone, said stream at its initiation being made up of from about 5 to about 25 parts by weight of particulate coal having a particle size of less than 65 microns and an initial temperature of less than 300° F., based upon the total weight of the coal and char being utilized in forming the stream and from about 95 to 75 parts by weight of particulate char having a particle size of less than 65 microns and an initial temperature ranging from about 1150° F. to about 1600° F. based upon the total weight of the coal and char being utilized in forming the stream; the residence time of said stream in the pyrolysis zone ranging from about 0.01 to about 3 seconds wherein

10 the particulate coal is heated to a temperature ranging from about 900° F. to about 1200° F.; removing the products produced in the pyrolysis zone and separating the char particles from the carrier gas and hydrocarbons produced upon pyrolysis of the coal.

20 In addition to the process for recovery of volatiles from agglomerative bituminous coal, we have also discovered that sulfur contamination can be readily removed when coal is processed in processes similar to this invention or in similar processes for non agglomerative coals by the addition of sulfur acceptors e.g., iron oxides, to the particulate coal prior to processing or by heating the products to high temperatures in the presence of hydrogen upon removal of the products from the pyrolysis zone. Our novel process provides those skilled in the art with 25 an efficient economical one step continuous process for the removal of volatiles from agglomerative bituminous coal with the added advantage of providing an efficient, economical method of desulfurizing coal.

BRIEF DESCRIPTION OF THE DRAWING

35 The drawing shows in schematic outline an arrangement of equipment for carrying out the novel processes of this invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

40 By the term high velocity stream is meant a stream of gas flowing through a pyrolysis zone, e.g. a pipe shaped reactor vessel, wherein the flow is turbulent in nature e.g. having a Reynolds flow index number greater than 2000. Laminar flow in the pyrolysis zone must be avoided, as such a flow system would tend to severely limit the productivity and rate of heat transfer within the pyrolysis zone. In the normal practice of this invention the char and coal solids are introduced into the bottom or top of the pyrolysis vessel and the char and coal are rapidly intermixed in the carrier gas and dynamically contacted with each other and blown through the vessel to permit the requisite heat transfer to take place. The heat required to remove the volatiles can be provided all or in part from either the sensible heat in the gas or in the char particles.

45 The inert carrier gases found useable in this invention to effectuate the prolysis of the coal particles must be non-reactive with the coal, char and hydrocarbons extracted from the coal during pyrolysis. This gas stream should be free of air, oxygen, water, carbon dioxide and the like as they have a very deleterious effect upon the proportion of volatiles extractable from the coal. Exemplary of gases suitable for use as carrier gases in our invention are, nitrogen, argon, CH₄, H₂, carbon monoxide and any other gas which will not deleteriously react with or oxidize the organic portion of the matter within the system.

50 55 60 65 70 75 80 85 90 95 The design of a particular system in which our process is to be utilized will of course have to conform to the

process limits as heretofore stated in the summary of the invention. The vessel must be designed with feed flow rates that will produce the requisite turbulence and heating of the particulate coal. Such design parameters are well known to those skilled in the art.

It must be understood that this invention is designed for the use of agglomerative particulate bituminous coal and that such coals are well known to those skilled in the art due to their tendency to plasticize and become sticky at relatively low temperatures i.e., 750-850° F. The term agglomerative bituminous in our invention is meant of course to include all other coals which may be agglomerative. The coal particles found useable in our invention can be prepared by any conventional method which will produce coal particles of the requisite size. Care should be taken to see that the exposure of the coal particles to oxygen sources are minimized to prevent oxidizing of the coal since such exposure will have a deleterious effect on yields from the process. For this reason we prefer to maintain the coal at temperatures below 300° F. prior to feeding it into the system as well as to prevent agglomeration.

The particulate char is added to the particulate coal in our invention both to prevent agglomeration and to provide at least a portion of the heat required for pyrolysis. The selection of a particular char-to-coal weight ratio will of course be dependent both upon the heat transfer requisites of the system as well as upon the degree of agglomerativeness of the coal particles. Since part of the heat of pyrolysis can be supplied by the carrier gas, the temperature, flow rate and residence time in the reactor must be calculated by well known methods for a particular system. In general for economy's sake we prefer to utilize the char particles for the main source of heat for the pyrolysis due to their density and the beneficial heat transfer coefficients built into the system.

The system is essentially designed to heat the agglomerative coal particles to a temperature ranging from 900° F. to 1100° F. to remove the maximum amount of volatiles therefrom. The selection of a particular temperature in this range will of course be dependent upon the particular coal employed and the residence time of the coal particles in the pyrolysis zone.

The effluent from the pyrolysis zone is composed of char, volatilized hydrocarbons, product gas, and inert carrier gas. The char solids can be readily separated therefrom by any conventional solids/gas separator such as a cyclone separator and the like. The volatilized hydrocarbons and carrier gas can be separated and recovered by conventional separation and recovery means.

By the term volatilized hydrocarbons as used in this application is meant the product gases produced by pyrolysis of the coal and in general these consist of condensable hydrocarbons which may be recovered simply by contacting the product gases with condensation means and noncondensable gases such as methane and other hydrocarbon gases which are not recoverable by ordinary condensation means such as methane, etc. The product gas stream also contains undesirable gaseous products such as CO₂, H₂S and water which should be removed from the product gas stream by conventional means such as chemical scrubbing, etc. After the condensable hydrocarbons and the undesirable gaseous products have been removed from the product gases, the scrubbed gases can be utilized as the inert carrier gas or at least as a portion thereof to contribute to the overall efficiency of the system.

Initially the system will be started up by using char from other sources, but after coal particles have had their volatiles removed, they will be useful as the source of char particles required by the system and will be produced in such excess that they will be readily utilizable in further processing to provide new materials which enhance the total economies of our process such as fuel

for use in a power plant or a source of raw materials for the chemical industry.

The excess char particles produced by our novel process can readily be degasified by heating them to temperatures ranging from about 1200° F. to 1800° F. to yield a hydrogen-rich gas stream which is saleable as premium fuel, or can be upgraded into pure hydrogen, or for hydrotreating the heavier volatilized hydrocarbons evolved during pyrolysis.

Char degasification can be carried out in several ways which, in substance amounts to indirect or direct heating. In direct heating, the char is contacted with sufficient oxygen from a suitable source, such as air, to bring the stream by controlled combustion up to the desired degasification temperature. This can be accomplished in a transport reactor similar to the pyrolysis reactor or in a fluidized bed reactor.

Preferably, the char is degasified by indirect heating which yields a gas stream containing 70 or more percent by volume hydrogen. This may be accomplished in a reactor similar to a tubular heat exchanger in which the char is blown through the tubes in a dense or dilute phase and fuel is burned with air or another suitable source of oxygen in adjacent tubes to supply the heat required for degasification.

Alternatively, the same result can be accomplished by the combustion of the fuel in tubes located in a fluidized bed of the char. After separating the char from the evolved gases, the char is cooled for ultimate use as a high grade fuel.

Where it is desired to produce a low sulfur char, sulfur reduction may be accomplished during pyrolysis, superheating and/or degasification of the resultant char.

One of the major problems faced in processing agglomerative bituminous coal and other types of coal, is pollution due to the presence of noxious sulfur compounds which are released upon processing. We have discovered that our novel process and similar processes can be efficiently and economically adapted to processes for removal of sulfur found in coal.

When coal having substantial amounts of iron pyrites (FeS₂) is processed in our invention or similar processes, the (FeS₂) is converted due to the heating of the char and the pyrrhotite is readily removable from the product solids by magnetic separation means.

Desulfurization during pyrolysis may also be achieved by having a solid sulfur acceptor, such as lime, present in the zone during pyrolysis. Preferably, however, iron oxide is used as the sulfur acceptor. The sulfur combines with the iron oxide to form pyrrhotite. Both are magnetic and may be removed, in addition to any iron pyrite naturally present, from the product char by magnetic separation. This can conveniently be accomplished with minimum cooling of the char to conserve the heat requirements for processing.

Desulfurization may also be achieved during pyrolysis by enriching the gas stream with hydrogen, preferably part of the hydrogen released during degasification. The hydrogen fed to pyrolysis zone reacts with sulfur to form hydrogen sulfide which is later removed by conventional means such as scrubbing, hydrogen also enriches the volatilized hydrocarbons. In the preferred embodiment of our invention we use a carrier gas containing at least 20 parts by volume of hydrogen based upon the total volume of carrier gas used.

Desulfurization may also be achieved during superheating of the char by employing as the transport gas, a gas enriched with hydrogen. This gas reacts with the sulfur in the char to achieve additional sulfur reduction of the product char. As with desulfurization during pyrolysis, the hydrogen employed may be obtained by the recycle of off gases from char degasification before or after purification,

Where it is desired to recover the sulfur from the product char, the char which is already at an elevated temperature is merely heated to about 2300° to 2800° F. at ambient pressures in the non-oxidizing environment for periods up to about 20 minutes. This results in substantial sulfur reductions from the char. In contrast to this, conventional calcination of petroleum coke requires much higher operating temperatures and longer residence time to achieve effective desulfurization.

When the char is degasified by indirect heating, maintaining pressure at from about 15 to about 100 p.s.i.a. and using a hydrogen-rich transport gas enhances additional sulfur removal during degasification. Under these conditions char can be desulfurized as well as degassed within reactor times of about ten minutes. This desulfurization can be achieved since the inorganic sulfur had been essentially removed by the sulfur acceptor in previous treatment.

A basic system which may be used to carry out the process of this invention is illustrated in the attached drawing. With reference thereto, the particulate agglomerative bituminous coal having a particle size of less than 65 microns which is fed as such, or after comminution during processing for removal of inherent values such as iron pyrites, to cyclone separator 10 when the particulate carbonaceous matter is separated from its carrier gas which is recycled. The compacted particles enter reservoir 12 for ultimate feeding to reactor 14, the feed to which is controlled by valve 16. The char required for the pyrolysis is stored in vessel 18 and its feed to reactor 14 monitored by control valve 20. When the char is superheated to provide the heat required for pyrolysis, reservoir 18 is suitably insulated or heated to maintain the char at its preferred feed temperature. Feed from reservoirs 12 and 18 are combined with inert gas supplied externally, or from another part of the process and fed to reactor 14 through line 8. Reactor 14 is generally a vertical tubular reactor. When processing agglomerative bituminous coal having excessive plasticity it may be helpful to use a reactor having porous walls through which an inert gas is continuously passed to prevent sticking of pyrolyzed particles to the surface of the reactor.

After pyrolysis, the char, volatilized hydrocarbons and inert transport gas are passed to cyclone 22 for separation of solids from the gases. Any fines which pass from cyclone 22 are separated in electrostatic separator 24 for return to the char product which is collected in reservoir 26. Where iron oxide is introduced to the particles in reactor 14 as a sulfur acceptor, there is positioned a magnetic separator either before cyclone separator 22 or between cyclone separator 22 and reservoir 26.

Separation of the char from the gas is preferably carried out without temperature reduction to conserve the process heat. In addition, reservoir 26 is suitably insulated to prevent heat loss. The char which is collected in reservoir 26 is preferably split into two streams which split can be effectuated and metered by valve 27. One constitutes recycle char and is preferably fed to superheater 28, and the balance fed to degassing unit 30.

Alternatively, all of the char from reservoir 26 may be sent to degassing unit 30 where, as a consequence of degasification, it is superheated to or above the temperature required for pyrolysis. A portion is withdrawn as product char and the balance returned to reservoir 36 for ultimate use as inert char in reactor 14.

When the char is passed to superheater 28, it is generally heated to a superheat temperature of from about 1150° F. to about 1600° F. Heating may be done directly by contacting the char with ambient or preheated air supplied from preheater 32 and inducing controlled combustion. Heater 28 may be a high velocity reactor similar to pyrolysis reactor 14 or a fluidized bed. It is preferred to conduct superheating at a temperature no greater

than about 1150° F. since above this temperature, evolution of hydrogen from the char is initiated and the hydrogen essentially lost as it is greatly diluted by the combustion gases.

5 Preheated char is then passed to cyclone 34 for solids-gas separation and to high temperature char reservoir 18.

The balance of the char removed from collector 26 is pyrolysed char and is passed to degasifier 30, shown here as a reactor in which the char is passed in indirect contact with hot products of combustion and raised to a temperature of from about 1200° F. to 1800° F. to dehydrogenate the char. The char and the hydrogen-rich gas then pass to cyclone separator 36 for solids-gas separation.

15 The hydrogen stream is passed to purification operations for removal of hydrogen-sulfide and carbon dioxide to generate a hydrogen stream suitable for use as a fuel for hydrogenation of hydrocarbons, and desulfurization of the char.

20 Char is collected in vessel 38 and can be removed therefrom through line 43 and valve 45 for ultimate use as a fuel for power plants or for use as char in pyrolysis portion of the system by being metered into the inert gas stream through line 41 and valve 39. Preferably, the 25 char is cooled in several stages after degasification and before passage to storage. The char may, for instance, be cooled to 1000° to 1200° F. by contact with water or steam to generate, by reaction, additional hydrogen and carbon monoxide and/or carbon dioxide.

30 The gaseous stream from electrostatic precipitator 24 is passed to a first condenser 40 where it is brought into contact with a water spray to generally cool it to about 500° F. for condensation of heavy hydrocarbons and tar-like products which are separated from the gas 35 stream. The gas stream is then passed through waste heat boiler 42 and into a second condenser 44 where lighter oils and water are condensed and separated into an oil phase and water phase. The water is recycled to condenser 40 and the oil decanted at the interface for recovery and sale or, where desired, for the processing.

40 The residual gas stream is then passed to absorber 46 where it is brought into contact with conventional absorbents for carbon dioxide and hydrogen sulfide. The pregnant absorbent is then passed to regenerator 48 where the hydrogen sulfide and carbon dioxide are separated to permit absorbent recycle.

45 Hydrogen sulfide and carbon dioxide are then preferably passed to a sulfur unit such as a Claus-type furnace for conversion to sulfur. The effluent gases from absorber 50 46 are then sold as product fuel gas or all or a portion of the effluent returned to the system as inert transport gas.

EXAMPLE I

55 The following example is given to illustrate the practice of our invention. Commercial nitrogen was utilized as the carrier gas to pass the agglomerative bituminous coal and char through the pyrolysis zone. The zone consisted of a pipe 10 feet long having an inside diameter of 1 inch which

60 was wrapped in electrically powered heating units to provide the heat for pyrolysis. 2.3 pounds per hour of mixture of char and coal particles having a maximum particle of 25 microns and a weight ratio of 3 parts char solids to one part coal solids.

65 The solids were heated to a temperature of 1025° F. in the pyrolysis zone. The flow rate of nitrogen through the zone during pyrolysis was maintained at 14 standard cubic feet per minute.

70 The system was operated for a period of one hour and both the product and the system were monitored to check for any deleterious effects arising due to agglomeration of the coal in the system. Minimal effects were noted but were so small as to permit the process to be carried out indefinitely without requiring steps to be taken to clean the pyrolysis zone. In fact the gas pressure differential

drop in the pyrolysis zone was less than 0.2 inch of water during the course of the experiment.

The yield of liquid hydrocarbons was equal to 37.9 percent of the initial dry weight of the coal. By comparison, the Fischer assay test (United States Bureau of Mines Publication 638 pages 47 through 56—1967) for the coal yield only 15.7 percent by weight of liquid hydrocarbons.

EXAMPLE II

To illustrate the effect of the use our novel process in preventing deleterious effects arising from the use of coal particles having relatively large particles sizes the following chart shows the results of four experiments carried out in accordance with the practice of Example I supra.

TABLE 1

Experiment Number	A	B	C	D
Particle feed rate, lb./min.	10.0	2.1	2.1	2.3
Maximum size of particles in feed	74	150	50	25
N ₂ flow rate (standard cubic ft./min.)	12.6	13.9	14.0	14.0
Inert particulate matter	Char	Silica	Silica	Char
Wt. ratio inert/coal particles	10/1	5/1	5/1	3/1
Pyrolysis temp., °F.	1,000	1,000	1,000	1,090
Pressure drop as measured in inches of water in pyrolysis zone				
Time, minutes:				
0	3.0	2.1	1.8	1.9
10	6.2	8.3	2.2	1.8
20	8.5	9.5	2.7	1.9
30	10.8	11.0	3.3	2.2
40	12.6	13.6	3.8	2.0
50	14.6	16.2	4.4	2.1
60	17.0	20.5	5.0	2.1

EXAMPLE III

The following illustrates the desulfurization of coal chars which had been degasified at 1600° F. Two char samples were passed to a thermal desulfurization zone at respective temperatures of 2540° F. and 2740° F. The sulfur content of the product char as a function of residence time in the desulfurization process is shown in Table 2.

TABLE 2

Time, minutes	Sulfur content of char, wt. percent, at—	
	2,540° F.	2,740° F.
0	2.75	4.00
3	1.80	1.55
10	1.55	1.00
20	1.37	0.77

EXAMPLE IV

This example is given to show the effectiveness of magnetic treatment of char to remove sulfur.

In this example samples of the unpyrolysed coal and pyrolysed char from Example I having a maximum particle size of 25 microns was run through a roll type high intensity magnetic separator. The magnetic separator was a model 127, high intensity induced roll magnetic separator produced by Carpco Research and Engineering Corporation run under test operating conditions of 3.0 amperes, with a splitter setting of 0, a drum speed setting of 80, a separation gap between rotor and magnet of 1/8 inch and a particulate coal or char feed rate of 2.6 grams per minute.

The initial sulfur content of the unpyrolysed particulate coal was 2.55 percent and the sulfur content of this particulate coal after it had been passed through the magnetic separator was 2.56% the initial sulfur content of the pyrolysed char produced in Example I was 2.57% and after the char particles had been passed through the magnetic separator the desulfurized char had a sulfur content of 2.01%.

It will be obvious to those skilled in the art that our novel process provides an efficient economical process for lowering the sulfur content of coal.

We have discovered that the yields of volatilized hydrocarbons from agglomerative bituminous coals which

are produced in our process are relatively sensitive to the pyrolysis temperature, and is optimum of 1,025° F. At this temperature approximately 36 percent by weight of the coal is converted to volatilized hydrocarbons. This represents a yield of synthetic crude oil of almost two barrels per ton of coal after hydrogenating, which is significantly greater than other conventional processes. The volatilized hydrocarbons produced in our process are much richer in the valuable low boiling compounds than tars produced in conventional processes. For example, about 20 percent of the volatilized hydrocarbons have a boiling point below 400° F.

What is claimed is:

1. A process for the pyrolysis of agglomerative bituminous coal to recover volatiles therefrom comprising:

(a) forming a high velocity stream composed of particulate agglomerative bituminous coal, particulate char and a substantially inert, nonoxidizing carrier gas in a pyrolysis zone, such that the char and coal particles are intimately admixed and entrained within the gaseous portion of the stream, the solids content of said stream in the zone ranging from about 0.1 to about 10 percent by volume based upon the total volume of the stream in the pyrolysis zone said stream at its initiation being made up of from about 5 to about 25 parts by weight of particulate agglomerative bituminous coal having a particle size of less than 65 microns and an initial temperature of less than 300° F. based upon the total weight of the coal and char in the stream, from about 95 to about 75 parts by weight of particulate char having a particle size of less than 65 microns and a temperature ranging from between about 1150° F. to about 1600° F. based upon the total weight of the coal and char being utilized in forming the stream; the residence time of said stream in the pyrolysis zone ranging from about 0.01 to about 3 seconds wherein the particulate coal is heated to a temperature ranging from about 900° F. to about 1200° F. to yield volatilized hydrocarbons and char products;

(b) removing the products produced from the heating and separating the solids portion thereof containing the particulate char produced therein from the gaseous stream composed of volatilized hydrocarbons and carrier gas; and

(c) separating and recovering the hydrocarbons from the gaseous stream.

2. The process of claim 1 wherein a portion of the solids produced by passage of the particulate coal and char through the pyrolysis zone is heated to a temperature ranging from between about 1150° F. to about 1600° F. and thereafter is utilized to form a portion of the high velocity stream.

3. The process of claim 2 wherein the particulate char utilized in the formation of said stream has a temperature of 1150° F.

4. The process of claim 2 wherein the solids content of said stream is 3 percent by volume based upon the total volume of the stream in the pyrolysis zone.

5. The process of claim 2 wherein the stream contains 90 parts by weight of char based upon the total weight of coal and char.

6. The process of claim 2 wherein the carrier gas is a hydrogen enriched gas stream.

7. The process of claim 2 wherein the agglomerative bituminous particulate coal contains sulfur and from about 1 to about 5 parts by weight of a particulate sulfur acceptor based upon the total weight of sulfur in the coal is admixed with the coal prior to forming the stream.

8. The process of claim 7 wherein the sulfur acceptor is particulate iron oxide.

9. The process of claim 8 wherein the sulfide of iron formed during pyrolysis are magnetically separated from the products produced by the pyrolysis of the particulate coal.

10. The process of claim 2 wherein the portion of the solids produced by passage of the particulate coal and char through the pyrolysis zone which is not recycled though the pyrolysis zone is heated in a degasification zone in the presence of an inert carrier gas to a temperature ranging between from about 1200° F. to about 1800° F. to form a hydrogen rich gas stream.

11. The process of claim 10 wherein the hydrogen rich gas stream is utilized as the inert carrier gas in the pyrolysis of the coal particles.

12. The process of claim 10 wherein the degasified char is heated to a temperature ranging between from about 2300° F. to about 2800° F. in the presence of an inert carrier gas.

13. The process of claim 10 wherein the volatile hydrocarbons produced upon pyrolysis of coal are catalytically hydrotreated with at least a portion of the hydrogen rich stream.

14. The process of claim 1 wherein the agglomerative bituminous coal contains sulfur and the inert carrier gas 20 contains hydrogen.

15. A process of claim 1 in which the solids removed after the heating are degasified and desulfurized by heating the solids to a temperature ranging between from about

2300° F. to about 2800° F. for a period of time up to about 20 minutes in the presence of an inert carrier gas.

16. The process of claim 1 wherein the particulate coal is heated to a temperature of about 1025° F. in the pyrolysis zone.

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