United States Patent [19]

Matthews

[11] **3,884,649**

[45] **May 20, 1975**

[54] **COAL PRETREATER AND ASH AGGLOMERATING COAL GASIFIER**

[75] Inventor: **Charles W. Matthews,** Darien, Ill.

[73] Assignee: **Institute of Gas Technology,** Chicago, Ill.

[22] Filed: **Oct. 29, 1973**

[21] Appl. No.: **410,476**

[52] **U.S. Cl.** **48/202;** 48/203; 48/206; 201/9; 201/31

[51] **Int. Cl.** **C10j 3/16**

[58] **Field of Search**.......... 48/202, 197 R, 206, 209, 48/210, 203; 201/9, 31, 38, 41

[56] **References Cited**

UNITED STATES PATENTS

2,336,466	12/1943	Chatterton et al.	48/206 X
2,582,712	1/1952	Howard	48/197 R X
2,687,950	8/1954	Kalbach	48/202 X
2,906,608	9/1959	Jequier	48/202 X
3,070,515	12/1962	Sylvander	201/9 X

Primary Examiner—S. Leon Bashore
Assistant Examiner—Peter F. Kratz
Attorney, Agent, or Firm—Molinare, Allegretti, Newitt & Witcoff

[57] **ABSTRACT**

Caking coal is converted to fuel gas by treatment in specific pretreatment and gasification zones. Pulverized coal is first pretreated by a mild oxidation in a fluid bed, with heat removal, at a temperature of about 700°–800 °F. to destroy the caking properties of the coal. The resulting gases and the pretreated coal are then passed to a fluid bed gasification zone maintained at the same pressure as the pretreatment zone. The fluid bed is positioned in the lower portion of the gasification zone and converts the coal to a gaseous mixture consisting essentially of CO, H_2, CO_2, and CH_4. However, small amounts of oils and tars are also evolved. The oils and tars in the gaseous mixture, are then thermally cracked in the upper portion of the gasification zone to produce a fuel gas relatively free of oils and tars. A specific feature of the pretreatment zone enables removal of high density inorganic materials.

6 Claims, 2 Drawing Figures

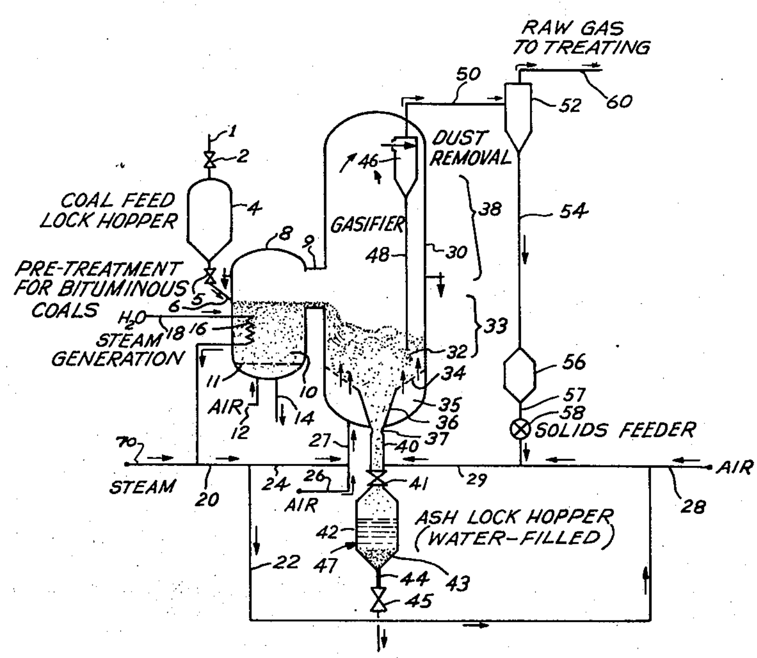


Fig. 1

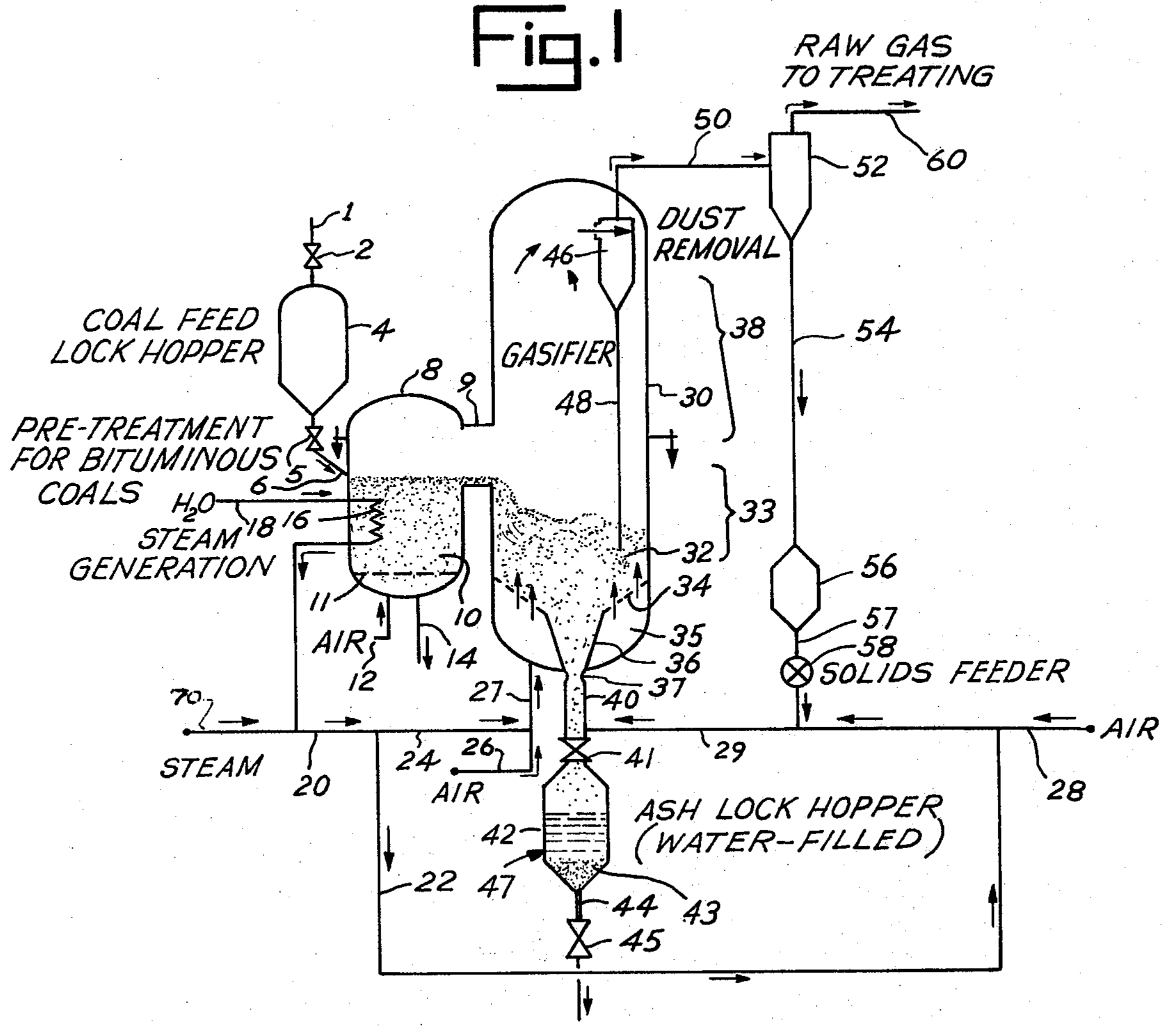
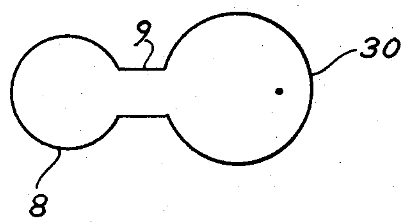

RAW GAS
TO TREATING
50
52
60
DUST
REMOVAL
46
1
2
COAL FEED
LOCK HOPPER
4
GASIFIER
38
54
8
9
48
30
PRE-TREATMENT
FOR BITUMINOUS
COALS
5
6
H_2O
18
16
33
STEAM
GENERATION
32
56
34
11
10
35
57
AIR
12
14
36
58
SOLIDS FEEDER
27
40
37
70
STEAM
20
24
26
AIR
41
29
AIR
28
ASH LOCK HOPPER
(WATER-FILLED)
42
22
47
44
43
45

Fig. 2


9
30
8

COAL PRETREATER AND ASH AGGLOMERATING COAL GASIFIER

BACKGROUND OF THE INVENTION

This invention relates to the production of fuel gas from coal. In particular, this process relates to coal gasification wherein the coal is processed through special pretreatment and gasification zones to prevent agglomeration of the coal during gasification and to produce a gas product that is relatively free of oils and tars.

One of the main sources of atmospheric pollutants today is from coal fired electric utility boilers. In these installations, a clean fossil fuel, such as natural gas, is not a practical substitute for coal in the generation of electricity because of its scarcity and cost. Furthermore, the available supply of clean fuel may combat pollution more effectively when used to fulfill residential and small commercial needs.

By way of example, the combustion products of coal contribute one-eighth of the total atmospheric pollutants emitted in the United States, including one-half of the sulfur oxides and one-quarter of both the nitrogen oxides and of the particulates. Sulfur emissions from coal combustion may be reduced by (a) using lowsulfur coal, (b) cleaning high-sulfur coal by physical methods, (c) removing sulfur oxides from coal combustion gases, (d) removing sulfur during the combustion step, (e) producing de-ashed lowsulfur fuel by solvent processing of coal, and (f) gasifying coal and removing sulfur from the gas before combustion.

The last method, coal gasification with gas cleaning before combustion, appears to offer the greatest reduction in sulfur emission since most of the sulfur in gasified coal appears as hydrogen sulfide. The removal of this hydrogen sulfide presents no great problem, however, since several different commercial gas cleaning processes are available today which can reduce the hydrogen sulfide content of gas streams from coal gasification to less than 10 ppm, and some processes can remove hydrogen sulfide to 1 ppm or less.

As mentioned, processes are known for the conversion of coal to a fuel gas. In Williams, U.S. Pat. No. 2,805,189, coal is pretreated in a fluid bed prior to gasification at a temperature below about 600°F. The resultant off gases are not recovered and a special solids transfer line is provided to insure that these gases do not enter the gasification reactor. This results in a loss of some volatile hydrocarbons, lowers overall process yield, and presents an additional gas stream that must be purified before disposal.

In Howard, U.S. Pat. No. 2,582,712, particulate coal is pretreated at 900° – 1400°F. in admixture with a large volume of residue from a gasification reaction zone. Specifically, about 15 – 30 units of hot residue from the gasification reaction are admixed with a single unit of fresh feed coal to rapidly heat the fresh feed to a noncaking temperature. This process requires the circulation of large amounts of residue thereby increasing the cost of the unit and subjecting the unit to considerable wear due to the abrasive nature of the residue.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a process for efficiently converting a caking carbonaceous material such as bituminous coal, by gasification, to a fuel gas relatively free of oils and tars containing hydrogen, carbon monoxide and methane.

It is another object of this invention to effectively pretreat a coal such as a caking coal, in a pretreatment zone to provide a noncaking feed for a gasification reaction zone wherein the pretreatment and gasification zones are in direct fluid communication and are maintained at the same pressure.

It is still another object of this invention to provide a method for removing gangue and other inorganic solid material from a coal feed prior to gasification.

The process of the present invention relates to the conversion of a finely divided carbonaceous material containing ash such as bituminous coal, to a fuel gas. In addition to a caking material such as bituminous coal, other solid carbonaceous material such as oil shale, tar sands, etc. may be processed according to the present invention. This fuel gas, also known in the art as producer gas or low BTU gas, has a heating value of between 100 – 300 BTU per cubic foot and prferably between 140 – 250 BTU per cubic feet, and is particularly suited for use in a fired boiler for the generation of electricity. In the first step of this process, a finely divided carbonaceous material, such as a coal pulverized to a size of about 0 × ¼ inches to 0 × ½inches is pretreated by mild oxidation with limited amounts of air at a temperature of about 700° – 800 °F. for a time sufficient to destroy the caking properties of the coal. Preferably the coal is pretreated at this temperature for about 10 to 30 minutes. This pretreatment is effected in a fluidized pretreatment zone and results in the oxidation of the surface of the particles to prevent agglomeration in the subsequent gasification step. Since heat is evolved during this mild oxidation step, it is necessary to withdraw heat from the pretreatment zone to maintain close control on the pretreatment temperature and to avoid inadvertant agglomeration or ignition of the coal particles in the fluidized pretreatment bed. This temperature control is preferably effected by indirect heat exchange with water to produce steam. This steam in turn is produced in sufficient quantities to supply all the steam required in the subsequent gasification step.

The pretreated carbonaceous material and the resultant gases are passed from the upper portion of the pretreatment chamber or zone directly to an adjacent gasification zone which is maintained at the same pressure as the pretreatment zone. The pressure of the gasification zone can be maintained at atmospheric or superatmospheric pressures depending on the quality of the gas desired. Higher pressures, in general, increase the BTU value of the product gas. The pretreated carbonaceous material is then maintained as a fluidized bed in the lower portion of the gasification zone by means known to the art and at conditions sufficient to convert the pretreated material to ash and a gaseous mixture of fuel gas, and small amounts of oils and tars. Oils and tar initially evolved during gasification represent about 3 to 4 wt. % of the pretreated coal that enters the gasifier. The ash is withdrawn from the bottom of the gasification zone and the gaseous mixture is passed to the upper portion of the gasification zone where the gaseous mixture in conjunction with the gases from the pretreatment zone are maintained at a temperature and time sufficient to thermally crack the oils and tars thereby producing a fuel gas essentially free of oils and tars. This upper portion of the gasification zone is maintained at a temperature above 1,000°F., preferably 1,200°– 1,500 °F., and the residence time should be about 10 – 100 seconds to convert the oils and tars to fuel gas components and carbon.

Typically, the gaseous mixture removed from the fluidized gasification bed contains a mixture of fine and coarse particulate material having a recoverable carbon value. This gas-solids mixture is separated in two stages to provide a coarse particulate fraction, and a fine particulate mixture. The coarse particle mixture is returned to the fluidized bed for recovery of the carbon contained therein and the fine particles in turn are passed to the bottom ash agglomerating section of the gasification zone. This agglomeration section is maintained at a temperature slightly higher than that of the fluidized bed by means known to the art to cause these fine materials to agglomerate with the ash removed from the fluidized gasification bed.

In addition, this invention removes shale, gangue, dirt, or rocks present in the coal prior to the gasification of the coal. If this material is passed to the gasification reaction, it can interfere with the removal of ash from the bottom of the fluidized bed and dilute the fluidized bed. Therefore, according to the present invention, this material, which as a density higher than that of the pulverized coal, is withdrawn from the lower portion of the fluidized pretreatment zone for disposal.

Other objects and embodiments will become apparent by reference to the following more detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side sectional view of a preferred apparatus used in the present invention and the various process flows embodied therein to convert coal to a fuel gas.

FIG. **2** is a top cross-sectional view of the pretreatment and gasification chambers taken along section line **2—2** of FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a pulverized caking bituminous feed coal, such as Illinois or Ireland coal, having a size in the range of less than about ¼ inches to about ½ inches enters via line **1** and is passed to feed lock hopper **4**. When lock hopper **4** is filled, valve **2** is closed, valve **5** is opened and the coal is passed to pretreat chamber or zone **8** via line **6**.

The pulverized coal passed to pretreatment zone **8** is maintained as a fluidized bed **10** above grate **11** by an oxygen containing gas such as air entering via line **12**. The amount of gas or air which enters pre-treatment zone **8** and the oxygen content of the gas are adjusted to oxidize about 10% of the carbon value of the coal passed to pretreatment zone **8**. This oxidation serves to merely oxidize the surface of the coal to prevent the coal from agglomerating when it is passed to the higher temperature gasification zone **30**. Typically, about 1 to about 1.5 SCF of oxygen minimum (as an air stream) are used per pound of coal passed to the pretreatment zone. As a consequence, the overall conditions within pretreatment zone **8** result in a deficiency in oxygen

and the off gases containing hydrocarbons and carbon oxides are essentially oxygen free. The temperature within pretreatment zone **8** is carefully controlled between 700°–800°F., preferably between 750°–800°F., by a cooling water stream **18** passing through heat exchange coil **16** positioned within fluidized bed **10**. The heat generated in the fludized bed by the controlled combustion or oxidation of the coal converts the water to steam thereby efficiently removing heat from the pretreatment zone as steam stream **20**. This steam stream **20** in turn is then passed to the gasification zone in a manner to be described in greater detail hereinafter to supply the steam required therein.

A specific feature of pretreatment zone **8** is the ability to remove slate, gangue, rocks, etc., present in the feed coal from the bottom of the pretreatment zone to prevent the passage of this material to the gasification zone. More particularly, the pulverized coal particles per se have a density appreciably less than the higher density gangue, rocks etc. As a consequence, as the air entering through line **12** passes through the openings in grate **11**, a selective separation of the lighter coal particles from the more dense gangue particles occurs. The concentration of gangue particles occurs immediately above grate **11** from which they may be selectively withdrawn via line **14** for suitable disposal.

The top portion of fluid bed **10** is allowed flow over and pass through conduit **9** to gasification chamber or zone **30**. It should be noted that gasification zone **30** is in direct fluid communication with fluid bed **10**. As a consequence, all of the gases generated in fluid bed **10** are passed directly to gasification zone **30**, and the pretreatment zone and gasification zone are maintained at the same pressure. The coal passed to gasification zone **30** is maintained as a fluid bed **32** positioned in the gasification section **33** of zone **30** by air and stream entering the bottom portion of the fluidized bed through conduits **27** and **29** in a manner known to the art which will be described in further detail hereinafter.

A single fluid bed **32** is illustrated in FIG. **1**. However, for production of higher heating value gas more than one fluidized bed may be used. In this embodiment, the pretreated coal would flow into an upper fluidized gasification bed which reacts with gases from a lower gasification bed. Unreacted char from the upper bed in turn would flow to the lower gasification bed. The coal in fluid bed **32** is converted by a known reaction with the air and steam to a mixture of hydrogen, carbon monoxide, methane, nitrogen and small amounts of oils and tars. The majority (i.e., 60–70%) of the steam required in the gasification reactor is withdrawn from the steam in line **20** after intermediate processing, not shown, as generated in pretreatment zone **10**, via line **24** and is admixed with air entering via line **26**. The resultant air steam mixture is passed to the lower portion of gasification zone **30** via line **27**, into a concentric solids free space **35** and passes upwardly through the openings in grate **34** to maintain fluid bed **32** in constant suspension, motion and circulation. Either make up steam or excess steam when produced can be added or removed respectively via line **70**. Of course, all of the steam required in the gasification zone can be added from an independent source via line **70**.

Fluid bed **32** proper is maintained at a temperature below the agglomeration temperature of the ash in the coal and preferably is maintained at a temperature above 1,500° and preferably about 1,700° – 1,900°F. This exact temperature is a function of a specific coal processed in the gasification zone and is readily determined without undue experimentation by those trained in the art.

The bottom section of gasification zone **30**, however, is maintained at a temperature above the agglomeration temperature of the ash and comprises an inverted conical shaped grate **34** sloped downwardly toward Venturi nozzle **36** in the manner illustrated in Jequier, et al., U.S. Pat. No. 2,906,608, the teachings of which are specifically incorporated by reference herein. Briefly, this inverted cone near the base of the gasification zone is maintained at a temperature greater than the temperature in the fluid bed **32** by the introduction of an air steam mixture entering via line **29** and is in the range in which the coal ash becomes sticky. At these high temperatures (i.e. 50° – 200°F. higher than the bed proper) the ash particles stick together and agglomerates are formed which can be withdrawn when they reach a predetermined size via pipe **40** and passed to lock hopper **42**. A portion of the steam produced in pretreater **8** is removed from line **20** via line **22** and admixed with air entering via line **28** and the resultant air steam mixture passed via line **29** to a point below constriction **37** in venturi nozzle **36** to create the high temperatures and separation desired. As described in greater detail in Jequier, et al., this air steam stream in constriction **37** is of sufficient velocity (such a greater than 40 ft/sec and preferably about 60 to 100 ft/sec) to prevent fine coal particles from flowing through constriction **37**. The ash particles, however, have a somewhat higher density than the coal particles, and although these ash particles do not initially have sufficient mass to fall downward through the gas flowing in venturi **36**, at the higher temperatures present within the throat of this nozzle the individual ash particles agglomerate together until they form a particle having sufficient mass to pass down through constriction **37**.

As indicated, the hot agglomerated ash particles are then passed to water filled lock hopper **42** wherein the ash is quenched by water entering lock hopper **42** through line **47**. The ash then settles as a layer **43** near the bottom of the hopper and is periodically discharged by closing valve **41**, thereby isolating the lock hopper from the gasifier, and, upon the opening of valve **45**, the water ash mixture is discharged, as a slurry, through conduit **44**.

The gases produced in fluid bed **32**, in admixture with the gases from pretreatment zone **8**, comprise a mixture of fuel gas (i.e. a mixture of hydrogen, carbon monoxide, carbon dioxide and methane), oils and tars and solid particulate matter. This gas-solids mixture is held in the upper cracking section **38** of the gasification zone, which is maintained at a temperature above 1,000°F., preferably 1,200°–1,500°, for at least 10 seconds to thermally crack the oils and tars that are present into gases and carbon. Cracking of these oils and tars increases the fuel value of the gas and avoids fouling problems in subsequent recovery sections. In any event, the gas solids mixture is passed to cyclone **46** and the larger particles are removed and passed via conduit **48** to fluid bed **32** for recovery of their carbon values. The resultant gas-solids mixture comprising fuel gas in admixture with very fine particulate matter is passed via line **50** to second cyclone **52**. In cyclone **52** raw product gas is recovered via line **60** for further treating by methods well known to those trained in the art. For example, product gas stream **60** after suitable heat recovery and pressure reduction can be passed to a Stretford unit for removal of any sulfur contained in the gas thereby producing a relatively pollution free fuel.

Fine solids are removed from cyclone **52** via line **54** and passed to storage bin **56**. Periodically, these fine solids are withdrawn via line **57** by solids feeder **58** and admixed with the air-steam mixture of line **29**. The resultant mixture is then passed to venturi nozzle **36**, below constriction **37**, wherein the carbon present on these fine particles is gasified and the very fine dust agglomerates with the ash for withdrawal from the system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Tabulated in Table 1 below are the product gases that can be produced according to the process of the present invention as illustrated schematically in FIG. **1**, when processing an Ireland Mine Coal. The product gases are the gases recovered after heat exchange to convert sensible heat to steam, expansion across a turboexpander to generate electricity, and sulfur removal by a Stretford process.

The operating conditions:

PROCESS CONDITIONS

Pretreater		
Pressure, psia	300	1000
Temperature, °F.	800	800
Residence Time, Min.	30	30
Gasifier		
Pressure, psia	300	1000
Temperature, °F.	1900	1900
Residence Time, Min.	40–60	40–60

PROCESS PERFORMANCE

Gasifier Pressure, psia	300		1000	
Product Gas	Wet	Dry	Wet	Dry
Heating Value, Btu/SCF				
Composition, vol. %	140	153	150	164
CO	17.8	19.4	12.5	13.7
CO_2	9.2	10.0	13.6	14.8
H_2	12.1	13.3	11.6	12.6
H_2O	8.5	—	8.5	—
CH_4	4.3	4.7	7.1	7.8
N_2	48.1	52.6	46.7	51.1
Total	100.0	100.0	100.0	100.0
Thermal Efficiency, %				
To all products	86.5		88.2	
To gas only	73.2		73.9	
To steam only	12.7		12.6	

The thermal efficiency of the process is determined by comparing the product heating value, heat contained in the steam produced, etc. to the heating value of the coal feed in a total utility gas facility. The 80+% efficiency obtained in producing utility gas compares favorably to the 60% efficiency obtained in coal gasification plants.

I claim as my invention:

1. A process for the conversion of a finely divided carbonaceous material containing ash to a fuel gas having a heating value of between 100 – 300 BTU per cubic foot which comprises:

i. pretreating a finely divided carbonaceous feed material by mild oxidation at a temperature of about

700°–800°F for about 10 to 30 minutes to destroy any caking properties of the carbonaceous feed material in a fluidized pretreatment zone;

ii. said fluidized pretreatment zone being in direct fluid communication with an adjacent gasification zone;

iii. withdrawing heat from the pretreatment zone by indirect heat exchange with water to produce steam and to maintain said pretreatment temperature;

iv. passing the pretreated carbonaceous material and the resultant gases from the upper portion of the pretreatment zone to said gasification zone and passing at least a portion of the steam produced in said pretreatment zone to said gasification zone;

v. said gasification zone being maintained at the same pressure as the pretreatment zone;

vi. maintaining the pretreated carbonaceous material as a fluidized bed in the lower portion of the gasification zone at conditions sufficient to convert said pretreated material to ash and a gaseous mixture of fuel gas and oils and tars;

vii. passing the gaseous mixture to the upper portion of said gasification zone above the fluidized bed and maintaining the gaseous mixture in the upper portion of the gasification zone at a temperature of about 1,200°– 1,500°F for about 10 – 100 seconds to crack the oils and tars in the gaseous mixture; and

viii. withdrawing ash from the bottom of said gasification zone.

2. A process as in claim **1** wherein said ash is agglomerated in the bottom portion of the gasification zone at a temperature above the temperature of the fluidized bed.

3. A process as in claim **2** wherein said gaseous mixture includes fine and coarse particulate material and said mixture is separated to provide a fine particulate fraction and a coarse particulate fraction, said coarse particulate fraction being passed to said fluidized bed in the gasification zone and said fine particulate fraction passed to the bottom portion of the gasification zone.

4. A process as in claim **1** wherein said finely divided carbonaceous material includes higher density inorganic material, said higher density material being withdrawn from the lower portion of said fluidized pretreatment zone.

5. A process as in claim **1** wherein the fluidized bed in said gasification zone is maintained at a temperature of greater than 1500°F and below the agglomeration temperature of the ash.

6. A process as in claim **1** wherein said carbonaceous material is bituminous coal.

* * * * *