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GASIFICATION OF CARBONACEOUS SOLIDS

Filed July 2, 1948

2 Sheets-Sheet 1

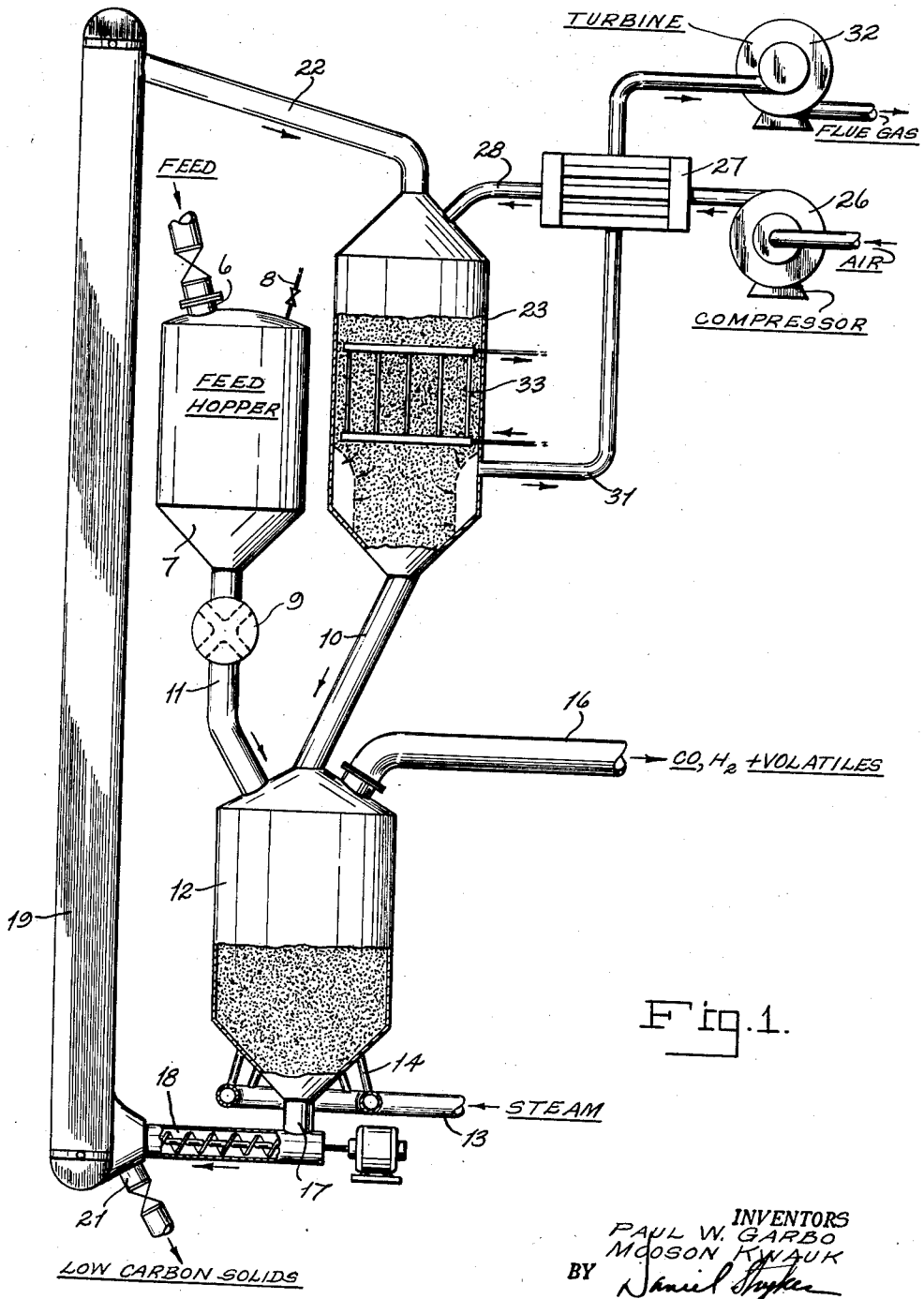


Fig. 1.

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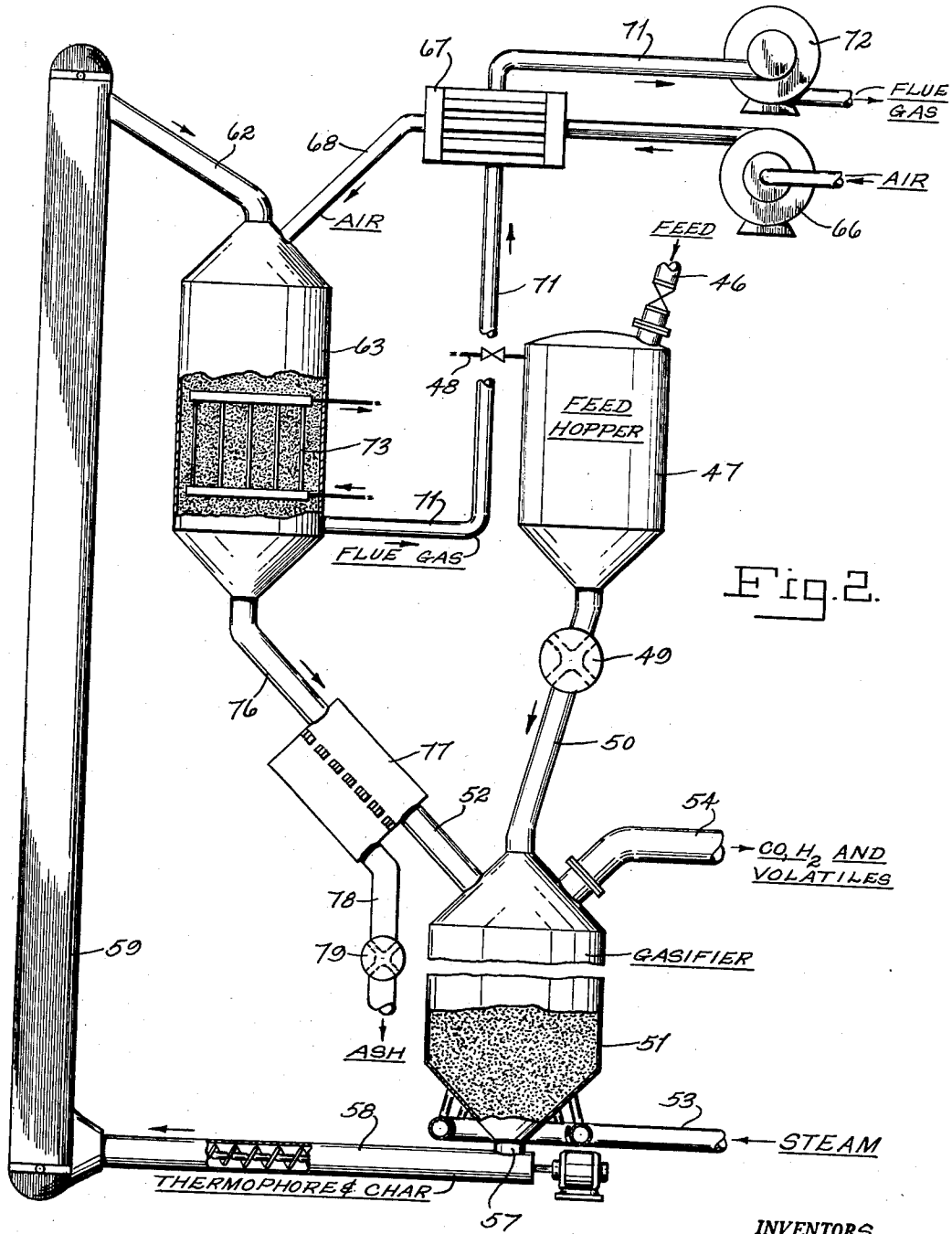


Fig. 2.

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GASIFICATION OF CARBONACEOUS SOLIDS

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This invention relates to a process for the gasification of a solid carbonaceous material. The process of this invention is applicable to the gasification of coal, lignite, coke, oil shale, and the like.

Gasification of carbonaceous materials may be accomplished by chemical reaction, for example by reaction with steam, carbon dioxide, etc. A partial gasification of carbonaceous materials containing volatilizable constituents may be accomplished simply by heating to a temperature sufficient to drive off volatile products by pyrolysis. Gasification of the carbonized material, or char, by chemical reaction, for example with steam, may be carried to substantial completion leaving a residual solid of low carbon content. The gasification reaction may be carried to any desired degree of completion; thus the carbon content of the residual solid may be varied from substantially zero to a considerable percentage of residual carbon. In operation, the percentage of residual carbon in the char generally depends upon uses for residual char, such as for fuel, etc. An elevated temperature is required for gasification as is known in the art.

An object of this invention is to provide an improved process for the gasification of solid carbonaceous material.

Another object is to provide a process for the gasification of solid carbonaceous material which is particularly applicable to carbonization and gasification of coal, lignite, oil shale and similar materials.

A further object is to provide an improved process for carrying out endothermic gasification reactions with a solid carbonaceous material and for supplying heat for said reactions.

A still further object is to provide an improved process for the gasification of coal or like carbonaceous material wherein air or similar oxygen-containing gases may be used to supply heat while the product gases are free from nitrogen.

Other objects and advantages will be apparent from the following detailed description and the accompanying illustrative drawings.

In accordance with the present invention, solid carbonaceous feed material is admixed with a solid thermophore or heat carrier material and subjected to an endothermic gasification reaction in a reaction zone. The heat carrier material is

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preheated to a temperature in excess of that required for the gasification and thus supplies at least a portion of the heat requirements for the endothermic gasification reaction. Since the heat of gasification is not generated by combustion with air within the gasification zone, the products of gasification are not contaminated by the usual products of combustion, viz., CO_2 and N_2.

The present process is particularly suited to endothermic reactions between carbon and a gaseous reactant, such for example, as steam in the water gas reaction. The steam used for gasification may be superheated. The reaction may be carried out with steam, with carbon dioxide or with both. Preferably, the reaction is carried to an extent such that a substantial portion of the carbon is reacted, leaving a residual carbonaceous material of low carbon content.

Residual carbonaceous material from the gasification zone and heat carrier material admixed therewith are transferred to a combustion zone wherein the carbon content of the residue is burned. In the combustion zone the residual carbonaceous material and the heat carrier material are contacted with a stream of an oxygen-containing gas, suitably air, under conditions such that substantially complete combustion of the carbon from the residual carbonaceous material takes place. This is accomplished most effectively in the present process by passing the air and mixture of residual carbonaceous material and heat carrier material concurrently through the combustion zone. Excess air is generally used so that the carbon is burned substantially completely to carbon dioxide, leaving substantially carbon-free ash. By passing air concurrently with the residual carbonaceous material, the lowest partial pressure of oxygen is co-existent with the highest temperature which exists at the bottom of the combustion chamber. This causes a uniform combustion rate. The heat carrier material is thus heated to a temperature in excess of the temperature in the gasification zone. Heat carrier material is returned to the gasification zone. The constricted passage between the two vessels affords a high resistance to the flow of the gases from one vessel to the other and thus prevents mixing of the gases. The heat carrier material may suitably comprise carbon-free re-

sidual solid resulting from gasification and combustion of the feed material. Thus, in processing coal the heat carrier material may comprise the ash. It is desirable, in some cases, to add a particulate solid inert material to the system as the heat carrier material. Preferably such added heat carrier material has a high specific heat and is of a form which is readily separable from the ash from the combustion zone. The heat carrier material may be granular or in formed shapes, for example, in the form of pebbles, pellets, or balls. Suitable materials for use as the inert heat carrier material comprise fused magnesia, alumina, zirconia, silicon carbide, sillimanite, mulite, zirkite, or other refractory materials, suitably in pebble form; or heat resistant alloy steels or other high melting point metals. The heat carrier material should be resistant to spalling under the reaction and combustion conditions.

An effective method of obtaining substantially complete combustion of the carbon in the residual carbonaceous material supplied to the combustion zone involves passing said material, admixed with heat carrier, downwardly through the combustion zone in a bed of considerable depth. Air preheated and under pressure is passed downwardly through the solid material in an amount sufficient to substantially completely consume the carbon by combustion. The highly effective utilization of the heating value of the residual carbon obtained by this means, results in maximum heating of the heat carrier material.

The combustion of the residual carbon in the combustion zone is preferably carried out under superatmospheric pressure. Pressures as high as, for example 1,000 pounds per square inch, may be used. In general, efficient combustion may be obtained with air at pressures ranging from 50 to 500 pounds per square inch gauge. The combustion zone and the reaction zone are generally operated at substantially the same pressure. The hot flue gases leaving the combustion zone preferably are utilized to preheat incoming air to a high temperature. After heat exchange, the flue gas may be passed through a gas turbine to recover energy therefrom. Under favorable conditions, the gas turbine may supply all of the power required for compressing the air to the pressure at which the combustion zone is operated.

In accordance with a preferred embodiment of this invention, the gasification reaction is carried out in a non-fluidized moving bed. Accordingly, solid carbonaceous feed material having a particle size suitable for relatively rapid reaction is charged to the gasification zone. The particles generally should have an average diameter of less than about one half inch and preferably less than about one quarter inch. The solid carbonaceous feed material and the heat carrier material at a temperature considerably in excess of the gasification temperature, are charged to the reactor. Generally, the heat carrier material, if it is an extraneous solid like pebbles, is of a particle size larger than that of the feed material. Steam is frequently used for the gasification and passed upwardly through and countercurrent to the flow of the mass of particles. In this way, an efficiency of operation is obtained, due to a temperature gradient along the vertical dimension of the bed, which cannot be obtained in fluidized beds. The countercurrent flow of solids and gas in the gasifier affords very favorable conditions for gasification. Sufficient heat carrier material is supplied to insure gasification of the major proportion of the carbon content of the carbonaceous material. The resulting residual carbonaceous material of low carbon content, together with admixed heat carrier, is withdrawn from the bottom of the bed and passed to the combustion zone. Usually, it is preferred that the residual carbonaceous material be controlled to have a carbon content sufficient only to supply the necessary heat to the heat carrier by combustion of the carbon with air in the combustion zone. Combustion is carried out as described hereinabove and resulting heated heat carrier material is returned to the gasification zone.

The invention will be more readily understood from the following detailed description of preferred embodiments illustrated in the accompanying drawings.

Fig. 1 is a diagrammatic elevational view, partly in cross section, of one form of apparatus suitable for carrying out the process of our invention.

Fig. 2 is a diagrammatic elevational view, partly in cross section, of an arrangement of apparatus suitable for illustrating another modification of the process of our invention.

The present invention will be described in detail with reference to coal as the carbonaceous material as typifying the operation and applications of the process of this invention. It will be understood that coal is used as a specific example and that the apparatus and method described are not limited to the use of coal as the carbonaceous feed material. Since the gasification of various solid carbonaceous materials is known in the art, the application of the present invention to other solid carbonaceous materials will be evident to one skilled in the art from the detailed description of this invention and illustrative examples of its application to treatment of coal.

With reference to the Fig. 1, ground coal, for example, is fed through line 6 into a feed hopper 7. An inert gas may be supplied to the hopper through line 8 to build up pressure in the hopper. The gas also forms an inert blanket avoiding explosion hazards.

Coal from the feed hopper 7 passes through a suitable valve 9, for example, a star valve conventional for handling solid materials, and is fed through line 11 to the gasification zone 12. Heat carrier material in the form of ash or residual solid substantially free from carbon is fed into the gasification zone through line 10. Steam is supplied to the bottom of the gasification zone from line 13 and distributed through tuyères 14. Carbon in the coal is reacted with steam by the water-gas reaction. Oxygen or other gaseous reactants may also be used if desired. The gas produced in the gasification zone is discharged therefrom through line 16 and is suitable for use as fuel gas, synthesis gas, etc. Residual carbonaceous material and heat carrier are withdrawn from the gasifier through line 17 from which they are transferred by a suitable conveyor 18 to an elevator 19. A portion of the low carbon content solid residual material or char from the gasifier may be discharged from the system through line 21. Solids from the gasification zone are carried upward by the elevator 19 and passed through line 22 into the combustion zone 23.

Air for combustion is compressed in a suitable compressor 26, for example a rotary compressor, passed through heat exchanger 27 where it is pre-

heated, and introduced through line 28 into the upper portion of the combustion zone. The air passes downwardly through the bed of residual carbonaceous particles in zone 23 concurrent to the flow of solid particles, effecting substantially complete combustion of the carbon content of said particles. The heat so liberated serves to heat the carbon-free residual solids which comprises ash, to a temperature substantially above that required for the gasification reaction.

The resulting hot flue gases from the combustion are separated from the carbon-free solid and passed through line 31 to the heat exchanger 27 wherein they serve to preheat the incoming air. The hot flue gases are then passed through a turbine 32 to recover energy therefrom. Power developed by the turbine 32 may be utilized for compression of the air in compressor 26.

Cooling tubes 33 may be provided in the combustion zone to remove a portion of the liberated heat, if desired. Where the heat liberated by combustion of the residual carbon is more than that required for carrying out the reaction in the reaction zone, cooling tubes 33 may be used for generation of steam, for example.

Hot solids from the combustion zone are discharged through line 16 into the gasification zone as the heat carrier to supply heat for the gasification reaction.

Fig. 2 of the drawings illustrates an embodiment of the present process wherein a solid refractory thermophore or heat carrier material is used. The heat carrier material is preferably in the form of solid particles of a size and shape such that it is readily separable from the ash resulting from combustion of the residual carbonaceous material from the gasification zone.

The crushed coal is fed through line 46 into the feed hopper 47. Pressurizing gas may be supplied to the feed hopper through line 48. Coal is fed from the feed hopper through a suitable valve 49 and line 50 into a gasification zone 51. Heat carrier particles at an elevated temperature are fed into the gasification zone through line 52. Steam is supplied to the gasification zone through line 53 for gasification of the carbon particles. Product gases are discharged through line 54. The residual solid carbonaceous material and thermophore are withdrawn through pipe 57 into conveyor 58 by means of which they are transferred to elevator 59. From the elevator, the char and heat carrier flow through line 62 into the combustion zone 63.

Air is compressed by compressor 66, preheated in heat exchanger 67, and passed through line 68 to the upper portion of the combustion zone. The air passes downwardly through the bed of solids comprising heat carrier particles and residual carbonaceous material from the gasification zone. The flue gas is withdrawn from the lower portion of the combustion zone through line 71, passed in heat exchange with the compressed air in heat exchanger 67, and then passed through a gas turbine 72.

Heat exchange means may be provided for removing excess heat from the combustion zone as, for example, a suitable tube bundle 73.

Residual carbon-free solid, or ash, and the heat carrier particles are discharged from the combustion zone 63 through line 76 into a separator 77. Here the heat carrier particles are separated from the ash. The separator 77 may suitably be a series of bars spaced along an incline over which the heat carrier particles pass while the ash falls through. The hot particles

of heat carrier material are returned to the gasification zone through line 52. The ash is discharged from the system through line 78 as controlled by valve 79.

Example I

Coal is gasified in an arrangement of apparatus as illustrated in Figure 1 of the drawings. Approximate analysis of the coal follows:

	Per cent by weight
Ash	20
Moisture	5
Fixed carbon	50
Volatile combustible matter	25

The heat of carbonization of the coal is 200 B. t. u.'s per pound.

The gasifier is designed to generate 24,000 mols of carbon monoxide and hydrogen per hour which is sufficient to yield approximately 6,000 barrels per day of liquid hydrocarbons by the Fischer-Tropsch type of synthesis process.

Coal is fed into the gasification zone, which is operated at 30 atmospheres pressure, at the rate of 250 tons per hour. Ash at 2100° F. is fed into the gasifier at the rate of 1,630 tons per hour into admixture with the coal. Steam is preheated to 900° F. and fed into the gasification zone at the rate of 12,000 mols per hour. Carbon monoxide, hydrogen and volatile combustible matter are discharged as product gases from the gasification zone at 2000° F. In addition to the 24,000 mols of carbon monoxide and hydrogen, 125,000 pounds per hour of volatile combustible matter is obtained. The volatile combustible matter may be recovered from the product gas and used for the manufacture of chemicals or it may be utilized in any other desired manner.

The residual carbonaceous material and ash is withdrawn from the carbonization and gasification zone at a temperature of 1000° F. Fifty tons per hour of this mixture is discarded from the system. The fixed carbon content of the discarded mixture is approximately 4 per cent or roughly 4,000 pounds. This material may find use as fuel for generation of steam. Residual carbonaceous material and ash at 1000° F. are passed at the rate of 1,698 tons per hour to the combustion zone. The combustion zone is operated at a pressure of 30 atmospheres.

Air, at the rate of 52,000 mols per hour is compressed to 30 atmospheres, heated to 900° F. by heat exchange with flue gases and introduced into the combustion zone at a point above the bed of ash and residual carbonaceous material. The power requirement for the air compression is approximately 114,000 horsepower. Flue gases leave the combustion zone at 2100° F. and are passed in heat exchange with the incoming air, effecting cooling of the flue gas to 1200° F. The flue gas is then passed through a gas turbine for recovery of power. Approximately 115,000 horsepower is available from the gas turbine. Flue gas, in the amount of 52,000 mols per hour at 520° F. is discharged from the gas turbine. The ash at 2100° F. is returned to the gasification zone to supply the heat of carbonization and gasification.

Example II

In a plant of the same capacity as that of Example I, refractory pebbles are used as a heat carrier in an arrangement of apparatus as illustrated in Figure 2 of the drawings. Operating pressures and temperatures are the same as for

Example I. Fused alumina pebbles are used as a heat carrier. Coal is charged into the gasifier at the rate of 240 tons per hour and admixed with 1,615 tons per hour of alumina pebbles. Steam at the rate of 12,000 mols per hour is supplied to the gasifier, producing 24,000 mols per hour of carbon monoxide and hydrogen and 120,000 pounds per hour of volatile combustible matter. The pebbles and 108 tons of residual carbonaceous material are passed to the burner. Air at the rate of 51,000 mols per hour is supplied to the combustion zone, requiring approximately 112,000 horsepower. Approximately 113,000 horsepower is recovered from the gas turbine. The pebbles, along with about 48 tons per hour of ash, are withdrawn from the burner. The ash is separated from the pebbles which are then returned to the gasifier.

Obviously many modifications and variations of the invention as hereinbefore set forth, may be made without departing from the spirit and scope thereof and, therefore, only such limitations should be imposed as are indicated in the appended claims.

We claim:

1. In a process for the gasification of a solid carbonaceous feed material by an endothermic gasification reaction, the improvement which comprises admixing said solid carbonaceous material in particle form with particles of a solid inert heat carrier material at a temperature substantially in excess of the temperature required for the gasification reaction, maintaining a bed of the resultant mixture of solids in a gasification zone, passing a gaseous reactant through said bed in said gasification zone to effect endothermic gasification of said solid carbonaceous material, withdrawing resulting gases from said gasification zone, discharging ungasified residue from said carbonaceous material admixed with said heat carrier material from said gasification zone, introducing said mixture withdrawn from said gasification zone into the upper portion of a combustion zone, maintaining a downwardly moving bed of solid heat carrier material and ungasified residue from said carbonaceous material in said combustion zone, contacting said bed in said combustion zone with a stream of oxygen-containing gas passing downwardly through said bed in an amount sufficient for substantially complete combustion of carbon in said mixture thereby heating said heat carrier material, withdrawing heated heat carrier material from the lower portion of said combustion zone, separating said particles of solid inert heat carrier material from residue from said carbonaceous material, and returning heated heat carrier material from said combustion zone to said gasification zone.

2. A process as defined in claim 1 wherein gasification of the carbonaceous material in the gasification zone is accomplished by reaction with steam.

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