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3,817,724

GASIFICATION OF SOLID CARBONACEOUS WASTE MATERIAL

Filed May 11, 1972

2 Sheets-Sheet 1

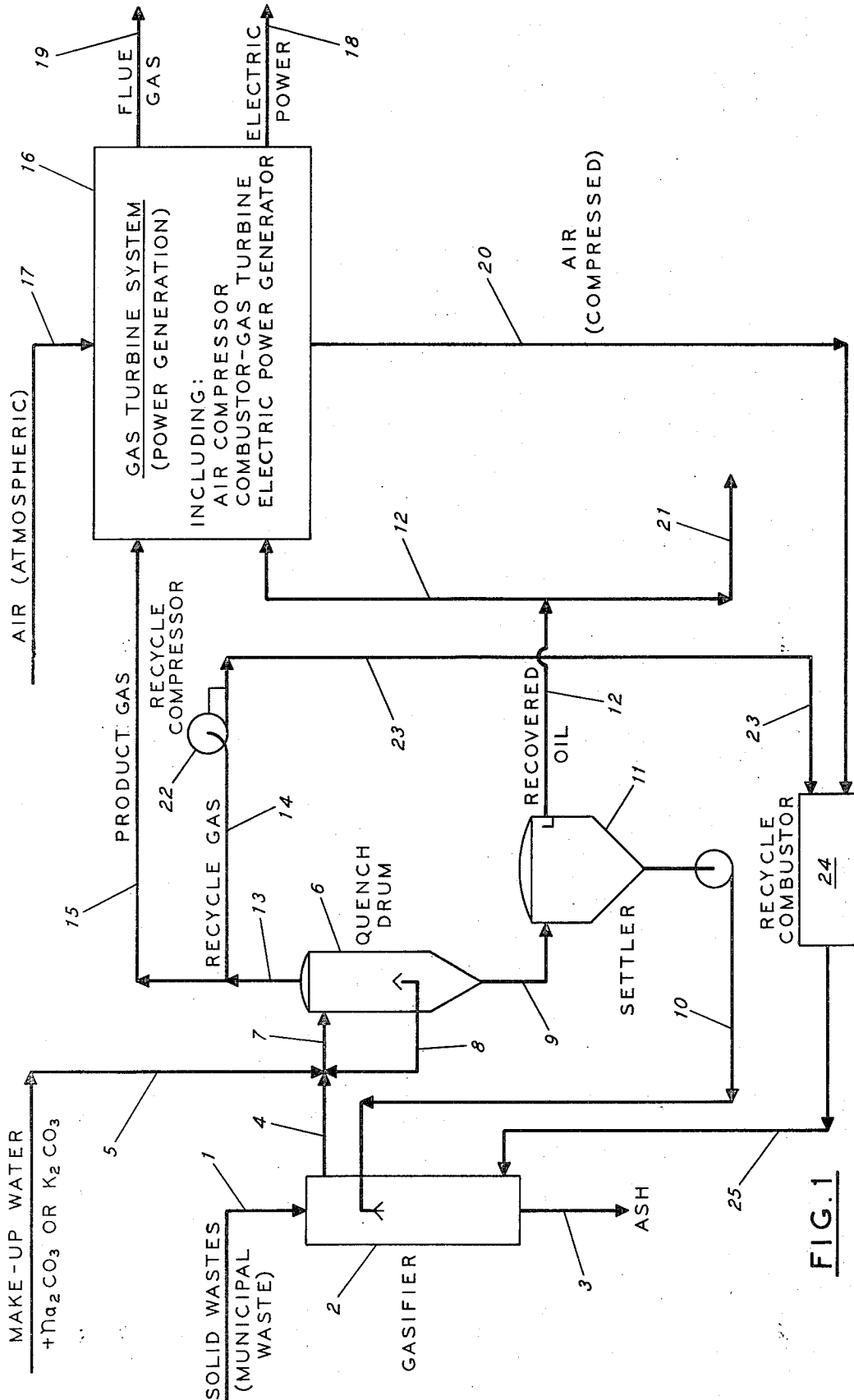


FIG. 1

GASIFICATION OF SOLID CARBONACEOUS WASTE MATERIAL

Filed May 11, 1972

2 Sheets-Sheet 2

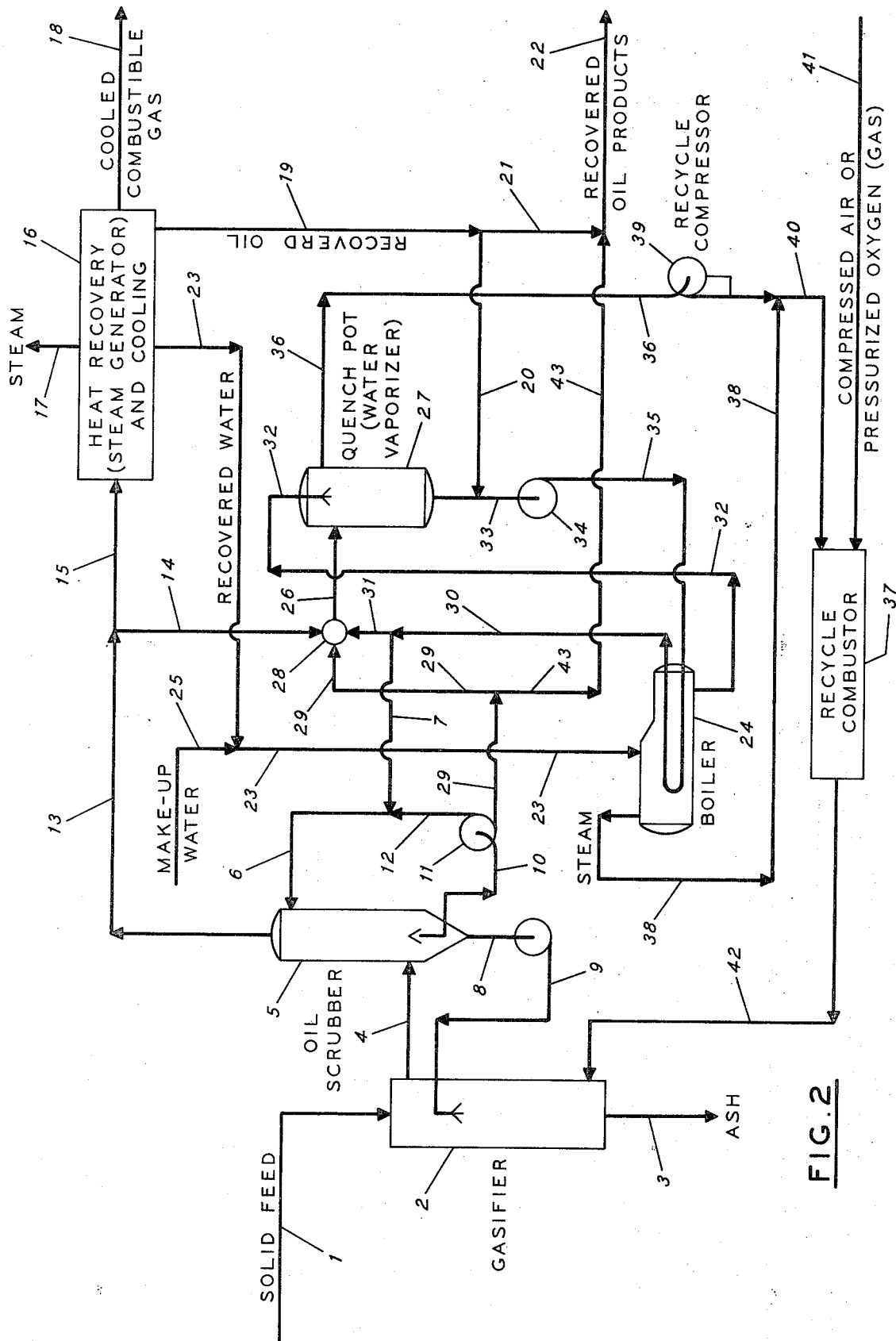


FIG. 2

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3,817,724

GASIFICATION OF SOLID CARBONACEOUS WASTE MATERIAL

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10 Claims

ABSTRACT OF THE DISCLOSURE

A process for converting solid carbonaceous waste material to combustible gases which comprises:

- (a) heating and reacting the carbonaceous waste material with reactive gases in a gasification zone to obtain said combustible gases and withdrawing the combustible gases from the gasification zone,
- (b) partially or wholly burning a portion of said combustible gases in a recycle gas combustion zone to obtain hot recycle gas containing essentially no oxygen, and
- (c) passing the hot recycle into the gasification zone to supply heat and said reactive gases to the carbonaceous material.

The process of the present invention can also be advantageously used for gasification of solid carbonaceous matter in general; however, certain modifications, such as in the reaction zone quench are preferably made when feeding lignite, coal, peat or the like to the gasification zone.

BACKGROUND OF THE INVENTION

The present invention relates to gasification of solid carbonaceous material, especially waste material.

Previous gasification methods for solids mostly fall into the classifications of eduction processes or partial oxidation processes.

Eduction type processes are described in U.S. Pat. No. 1,055,334, "Process of Making Gas," U.S. Pat. No. 2,640,014, "Oil-Shale Eduction Process and Apparatus"; and U.S. Pat. No. 3,361,644, "Shale Retorting Process."

According to the U.S. Pat. No. 1,055,334, process gas is obtained from coal by distillation comprising passing the gas-making material between heated walls in a finely divided condition and while separated and distributed in a substantially non-oxidizing medium and distilling the material during such passage and regulating the motion of the material and said medium by imparting thereto a vertical motion by jets of heated gas directed along the heated walls transversely to the direction of passage.

It can be noted, however, that coal distillation is not gasification. Distillation drives off volatile matter already present; gasification creates volatiles not originally present.

In the process of U.S. Pat. 2,640,014, part of the material left after eduction of oil from the shale feed is burned to ashes with the resulting hot gas then being used to educt gas and oil from the shale feed material.

According to U.S. Pat. 3,361,644 gases and oil are educted from shale by passing oxygen-free hot gas countercurrent to downflowing shale particles. The hot gas is obtained by heating a portion of the gas effluent from the eduction zone. Temperature is maintained below about 1800° F. in the eduction zone to avoid clinker formation by fusion of ash constituents. The process of U.S. Pat. 3,361,644 is largely a pyrolysis-distillation process which is not based on a gasification reaction such as reacting H₂O with carbonaceous material.

Partial oxidation processes are described, for example, in U.S. Pat. Nos. 1,977,684; 2,592,377; 2,657,986; 2,633,417; 2,727,812; 2,987,387; 2,657,124; and 3,025,149.

These processes all involve injection of oxygen into the reaction zone. Also, steam is usually injected into the reaction zone.

U.S. Pat. No. 2,660,521 is directed to partial oxidation of gases with expansion of the resultant hot gases through a turbine and thereby generating power and obtaining a cooled synthesis gas. Temperature in the reaction zone is controlled by carbon dioxide recycle. The carbon dioxide is a diluent and also lowers temperature by virtue of the endothermic reaction of carbon dioxide with hydrocarbon to form carbon monoxide and hydrogen.

Production of hydrogen and other combustible gases from waste substances produced in the manufacture of paper from wood chips and the like has been discussed in the literature, as, for example, in U.S. Pat. 3,317,292. In the manufacture of paper, wood chips are digested, for example, with an aqueous calcium sulfide liquid thereby forming calcium lignin sulfonate waste product in solution, leaving wood pulp behind. As disclosed in U.S. Pat. 3,317,292, the waste substances containing lignin-derived organic components can be converted to a gas mixture comprising hydrogen by contacting the waste material with steam in a reaction zone at an elevated temperature at least of the order of several hundred degrees centigrade.

Both U.S. Pat. No. 1,777,449, titled "Process of Producing Gas From Garbage" and U.S. Pat. 3,471,275, titled "Method of Disposal of Refuse," are directed to producing combustible gases in an externally heated retort rather than by introducing hot gases directly into the retort vessel.

Combustible gases produced by the present invention may be utilized in processes which burn the gas and produce energy by expanding the resultant hot gases through a turbine. Gas turbines are now operating on fuel gas (natural and refinery), blast-furnace gases, fuel oils (including heavy residuals), and at least one gas turbine burning gas generated from coal is operating.

As described in a report titled "New Fossil-Fueled Power Plant Process Based on Lurgi Pressure Gasification of Coal" by Paul F. H. Rudolph, delivered at an ACS meeting on May 27, 1970, gas turbines burning gas generated from coal are used at Lünen in West Germany to drive electricity generators. As disclosed in that report, carbon or coal can be gasified in the presence of oxygen (or air) and steam at a temperature of 790° C. (1454° F.). Gases from the gasification zone, which consist largely of CO and H₂, are purified to remove coal dust and fly ash which are detrimental to the operation of gas turbines. After purification of the gases from the gasification step, the gases are heated in exchange with incoming air, expanded through a turbine which drives the second stage air compressor, then combusted with air, and then expanded through a gas turbine which turbine is used to drive an electricity generator and first stage air compressor. The amount of air introduced to the combustor chamber is just that required to burn the gases. Heat is removed from the combustor by steam generation so that the inlet temperature to the gas turbine is about 820° C. (1508° F.).

The Rudolph report is directed to the gasification of coal and also mentions that other gasification plants are used to gasify similar material such as sub-bituminous coal and lignite. The Rudolph process calls for injection of oxygen directly to the gasification zone and also the injection of steam to aid in controlling the temperature in the reaction zone.

SUMMARY

According to the present invention a process is provided for converting solid carbonaceous waste material to combustible gases which comprises:

- (a) heating and reacting the carbonaceous waste material with reactive gases in a gasification zone to obtain said combustible gases and withdrawing the combustible gas from the gasification zone,
- (b) partially or wholly burning a portion of said combustible gases in a recycle gas combustion zone to obtain hot recycle gas containing essentially no oxygen, and
- (c) passing the hot recycle into the gasification zone to supply heat and said reactive gases to the carbonaceous material.

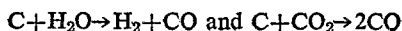
The present invention, among other features, is based on the combination of carbonaceous waste solids gasification with temperature control in the gasification zone obtained by partially or wholly burning a portion of the effluent gases from the gasification zone and then recycling the hot gases thus obtained to the gasification zone. It is critical in the process of the present invention that gasification reactions are carried out in the gasification zone to generate hydrogen from hydrocarbonaceous matter in the gasification zone and also to generate hydrogen from the H₂O which is added to the reaction zone via the recycled hot gases. The present invention is also based on a critically important third feature or concept which is that the present process is extremely attractive for the conversion of solid carbonaceous wastes to combustible gas. The term "solid carbonaceous waste material" is used herein to connote municipal garbage, industrial or agricultural wastes which are organic, such as cellulosic solids, dried or partially dried sewage, and like solid carbonaceous waste materials.

Still another critical aspect of the present invention is the reuse of H₂O which is vaporized by reactor effluent scrubbing or quenching.

Unlike the process as described, for example, in the Rudolph report referred to previously, in a process of the present invention no auxiliary steam or oxygen is introduced to the gasification zone. Instead, in the process of the present invention the maximum temperature is highly advantageously controlled in the gasification zone by means of adjusting external to the gasification zone the temperature of hot recycle gas to the gasification zone.

The temperature in the gasification zone can, of course, be controlled pursuant to the present invention by controlling both the amount of hot recycle gas and the temperature of the recycle gas. Usually both of these will be adjusted to an optimum level for the process of the present invention so as to achieve desired reaction rates of solids in the gasification zone at minimum energy requirement for recycle gas compression, but yet to maintain temperatures in the gasification zone below the ash fusion temperature, e.g., below about 2000° F. The partial burning of the recycle gas to the gasification zone can be carried out, for example, by an "in-line" burner.

The gases obtained from the gasification zone are preferably cooled and cleansed by a water quench. This water in part finds its way back to the gasification zone via that portion of the gases which are recycled to supply heat and reactant gases to the gasification zone. Additional water is supplied to the gasification zone from the solids fed to the gasification zone, as the solids fed invariably will have at least some moisture content. Additional water and carbon dioxide are produced by partial burning of the recycle gas. Thus, there will be H₂O and CO₂ present in the gasification zone for conversion of carbon and hydrocarbons into hydrogen and carbon monoxide according to well known reactions such as



The portion of the gasification zone gases which are not recycled to the gasification zone are preferably utilized in a manner previously described by the Rudolph report.

The process of the present invention can also be advantageously used for gasification of solid carbonaceous matter in general; however, certain modifications, such as in the reaction zone quench, are preferably made when feeding lignite, peat, coal or the like to the gasification zone. When feeding lignite, peat, pulverized coal or the like to the gasification zone, the raw hot gases from the gasification zone are preferably not immediately quenched with water, but instead are first quenched with an oil stream to remove particulate matter and thereby allow advantageous heat recovery from a portion of the gasification zone effluent without incurring severe heat exchanger fouling.

BRIEF DESCRIPTION OF THE DRAWING

The drawings are schematic process flow diagrams illustrating preferred embodiments of the present invention as applied to gasification of municipal waste type feedstocks (FIG. 1) and as applied to gasification of lignite, coal, peat or the like (FIG. 2).

DETAILED DESCRIPTION OF THE DRAWING

Referring more particularly to FIG. 1, solid wastes are introduced via line 1 to gasification zone 2. The solid wastes can be chosen from a variety of feeds such as municipal garbage (paper, orange peels, grease, bones, plastics, etc.); agricultural wastes (corn stalks, etc.); sewage, preferably in dried form; and the like.

The solids can be considered to undergo a series of steps of reactions in the gasification zone including, for example, H₂O distillation, oil distillation, pyrolysis, and gasification reactions such as previously mentioned. In the present invention there must be gasification reactions in the gasification zone.

Ashes are withdrawn from the bottom of the gasification zone as indicated via line 3.

A gaseous stream is withdrawn from the gasification zone as indicated by line 4. This gas stream is quenched and scrubbed to remove particles by water introduced to quench drum 6 via line 7 and recycle line 8. Make-up water and alkali carbonate is introduced via line 5 to react with strong acids such as HCl that may form in the gasifier and to also vaporize most of the water for efficient use in the gasifier. A small portion of the makeup water is ultimately recycled as a solids-containing sludge via lines 9 and 10 to gasifier 2. The water preferably carries reacted alkali carbonate to the gasifier which also provides catalytic benefits for the reaction of solid waste material in gasifier 2 as is further described in the commonly assigned application of R. J. White, titled "Catalytic Hydrogen Manufacture," filed May 5, 1970, Ser. No. 34,844.

Heavy sludge material and water are withdrawn from quench drum 6 via line 9 and passed to settler 11. Oily sludge material, water and preferably reacted alkali carbonate is passed to gasifier 2 via line 10 from the settler. A clarified oil stream is withdrawn from an intermediate point from settler 11 via line 12.

The hot gases withdrawn from gasifier 2 via line 4 are at a temperature of about 600° F., and the water scrub in the quench drum results in them being cooled to a temperature of about 350° F. to 450° F. before they are removed via line 13.

The gaseous material in line 13 is then split into two streams; first stream 14 for alternate recycle back to the gasification zone, and a second stream 15 which can be referred to as a product gas stream.

The product gas stream is preferably introduced to zone 16 for power generation preferably using a gas turbine system similar to that referred to in the Rudolph report previously and/or steam generation. Alternatively, the product gas in line 15 can be used in other manners as a low B.t.u. fuel or as feed to synthesis gas processes,

for example, processes requiring the use of hydrogen and/or carbon monoxide. In the latter case, pure oxygen will be supplied to the in-line burner 24 via line 20 rather than air as shown.

Recovered oil is shown as being passed from the settler to the power generation system via line 12. Alternatively, the recovered oil can be removed as a product as indicated by line 21.

Electric power is preferably generated in zone 16 by an electrical generator driven by a gas turbine, which gas turbine is in turn driven by combusted product gases and combusted recovered oil, as desired, introduced via lines 15 and 12, respectively. The electric power is schematically indicated as withdrawn via line 18. Flue gas resulting from burning the product gas, to supply power in zone 16, is shown as withdrawn via line 19.

A portion of the power generated by the gas turbine in zone 16 is preferably used for driving an air compressor to provide compressed air for combustion in zone 16 and, as indicated by line 20, for use in recycle combustor 24. Air to the compressor is shown entering zone 16 via line 17.

The recycle gases from quench drum 6 are passed to the recycle combustor via recycle compressor 22 and then line 23. Compressed air or pressurized oxygen is introduced to recycle combustor 24 via line 20. Recycle combustor 24 is preferably an in-line burner device.

The partially combusted recycle gas is withdrawn from recycle combustor 24 usually at a temperature of about 1700° F. and passed via line 25 to the bottom of gasification zone 2 to supply reactive gases and temperature control as well as the necessary heat for gasification zone 2.

Referring now particularly to FIG. 2, carbonaceous solids are introduced via line 1 to gasification zone 2. The carbonaceous solids can be chosen from a variety of feeds such as lignite, or peat, or coal, or wood, or cellulose, or other solid carbonaceous materials. However, the solids are not a wide ranging mixture as in the previously described embodiment relating to a "waste" material feed such as municipal waste. Preferably, the carbonaceous solids are in pulverized form to increase the reactivity of the solids and permit more uniform flow into the apparatus.

The solids can be considered to undergo a series of steps or reactions in the gasification zone including, for example, H₂O distillation, oil distillation, pyrolysis, and gasification reactions such as previously mentioned. In the present invention there must be gasification reactions in the gasification zone.

Ashes are withdrawn from the bottom of the gasification zone as indicated via line 3.

A gaseous stream is withdrawn from the gasification zone as indicated by line 4. This gas stream is quenched and scrubbed to remove particles by oil introduced to quench drum 5 via line 6 and recycle line 7. Heavy sludge material is withdrawn from oil scrubber 5 via line 8 and returned to the gasifier via line 9 for further conversion to product combustible gases. A clarified oil stream is withdrawn from an intermediate point from oil scrubber 5 via line 10. This clarified oil stream is recirculated via pump 11 and then lines 12 and 6 to the upper part of the oil scrubber where it is introduced to scrub the hot gases which are introduced to the scrubber via line 4. The hot gases are introduced to the scrubber at a temperature of about 1000° F., and the oil scrubbing process results in them being cooled to a temperature of about 700-800° F. before they are removed via line 13.

The gaseous material in line 13 is then split into two streams; a first stream 14 for alternate recycle back to the gasification zone, and a second stream 15 which can be referred to as a product gas stream.

The product gas stream is introduced to a heat recovery and/or steam generation zone 16 wherein steam can be generated as indicated by line 17 leaving zone 16. The

product gas is withdrawn via line 18 from the heat recovery zone 16. This product gas is then passed to further processing and use, for example, further processing for sulfur removal from the gas followed by use of the gas as a low B.T.U. fuel or as feed to synthesis gas processes, for example, processes requiring the use of hydrogen and/or carbon monoxide.

Recovered oil is also withdrawn from zone 16 as indicated by line 19. The recovered oil can be used within the process as indicated by line 20, or the recovered oil can be removed as a product as indicated by lines 21 and 22.

Recovered water (waste water) is removed from zone 16 via line 23 and preferably is used internally in the process of the present invention as can be seen by reference to boiler 24. Makeup water which may be necessary in the process of the present invention can also be added to boiler 24 as indicated by lines 25 and 23.

Referring now again to the gases from the gasification zone, that is, the recycle portion of the gases from the gasification zone, these gases are passed via line 14 and then 26 into quench pot 27. Before introduction into quench pot 27, oil is sprayed into the recycle gas at junction 28. Junction 28 receives oil that has been withdrawn, for example, via lines 10 and 29 from oil scrubber 5, and oil may also be added to the recycle gas at junction 28 via lines 30 and 31 from boiler 24 as shown in the drawing.

The recycle stream containing oil which has been sprayed into the stream at junction 28 is introduced via line 26 to quench pot 27 wherein the hot recycle gas is further cooled, preferably by vaporization of hot blowdown water (waste water) from boiler 24 which is introduced to the quench pot via line 32. The use of hot blowdown water to quench the hot recycle gases is a particularly preferred mode of carrying out the present invention as it contributes to a relatively high efficiency for the overall process of the present invention, while eliminating waste disposal problem.

Oil is withdrawn from the bottom of the quench pot via line 33 and is pumped via pump 34 to the boiler 24 via line 35.

Quenched recycle gases are removed at a temperature of about 350° to 500° F. via line 36 from the quench pot containing a sufficient amount of water vapor for the gasification reaction in zone 2, including water which is formed by combustion in combustor 37 to achieve the temperature control of the gasification reaction in zone 2.

However, the amount of recycle gas, as well as the temperature of the recycle gas leaving recycle combustor 37, is the primary variable in controlling the maximum temperature and reaction rate in gasification zone 2. Also, as shown on the drawing, the amount of water vapor in the recycle gas to the gasifier can be augmented by steam from boiler 24 with the steam being added to the recycle gas as shown by line 38. Additional steam may also be produced from boiler 24 via line 43. Thus, the amount of H₂O fed to the gasifier is controlled in the process of the present invention by the amount of water vaporized into the recycle gas in quench pot 27; secondly, by the amount of steam introduced into the recycle gas via line 38; and, thirdly, by the amount of gases combusted and the temperature of combustion in recycle combustor 37.

The recycle gases from quench pot 27 are passed to the recycle combustor via recycle compressor 39 and then line 40. Compressed air or pressurized oxygen, depending on the ultimate use for the product gas, is introduced to recycle combustor 37 via line 41. Recycle combustor 37 is preferably an in-line burner device.

The partially combusted recycle gas is withdrawn from recycle combustor 37, usually at a temperature of about 1900° F. and passed via line 42 to the bottom of gasification zone 2 to supply reactive gases and temperature control as well as the necessary heat for gasification zone 2.

Although various embodiments of the invention have been described, it is to be understood that they are meant to be illustrative only and not limiting. Certain features may be changed without departing from the spirit or scope of the present invention. Accordingly, the invention is not to be construed as limited to the specific embodiments or examples discussed, but only as defined in the appended claims or substantial equivalents of the claims.

What is claimed is:

1. A process for converting solid carbonaceous waste material to combustible gases, which comprises:
 - (a) heating and reacting the waste material with reactive gases in a gasification zone to obtain said combustible gases and withdrawing the combustible gases from the gasification zone, said gasification zone being essentially free of molecular oxygen, and said heating being to a gasification temperature;
 - (b) partially or wholly burning a portion of said combustible gases in a recycle gas combustion zone to obtain hot recycle gases essentially free of molecular oxygen; and
 - (c) passing the hot recycle gases into the gasification zone to supply said heating and said reactive gases for the reaction with the waste material.
2. A process as in claim 1, wherein the temperature in the gasification zone is maintained below the ash fusion temperature of the resulting ash by means of adjusting the temperature of said hot recycle gases prior to said passing to the gasification zone.
3. A process as in claim 1, wherein the temperature in the gasification zone is maintained below the ash fusion temperature of the resulting ash by means of adjusting the amount of said hot recycle gas supplied to the gasification zone.
4. A process as in claim 2, wherein said temperature is adjusted by quenching the combustible gases with water prior to the burning.
5. The process as in claim 4, wherein the water used for the quenching is passed to a steam boiler to supply heat for the generation of steam and the resulting steam is combined with the portion of the combustible gases prior to said burning.
6. A process for converting solid carbonaceous material to combustible gases, which comprises:
 - (a) heating and reacting said material with reactive gases in a gasification zone to obtain said combustible gases and withdrawing the combustible gases from the gasification zone, said gasification zone being essentially free of molecular oxygen, and said heating being to a gasification temperature;
 - (b) partially or wholly burning a portion of said combustible gases in a recycle gas combustion zone to

- obtain hot recycle gases essentially free of molecular oxygen; and
- (c) passing the hot recycle gases into the gasification zone to supply said heating and said reactive gases for the reaction with the material.
 7. A process for converting solid carbonaceous waste material into combustible gases, which comprises:
 - (a) forming said combustible gases by heating and reacting said waste material with hot reactive gases in a gasification zone, said heating being to a gasification temperature;
 - (b) withdrawing said combustible gases from the gasification zone and cooling and cleansing said withdrawn gases by a water quench;
 - (c) passing said quenched gases to a gas combustion zone and forming said hot reactive gases by wholly or partially burning a portion of said quenched gases in the combustion zone, said reactive gases containing essentially no oxygen; and
 - (d) passing said hot reactive gases into the gasification zone to supply said heating and reactive gases for the reaction with said waste material.
 8. A process as in claim 7 wherein the quench water contains alkali carbonate.
 9. A process as in claim 7 wherein:
 - (a) said withdrawn combustible gases are at a temperature of about 600° F.; and
 - (b) said quenched gases are at a temperature in the range from about 350° F. to 450° F.
 10. A process as in claim 9 wherein electrical power is generated by combusting the balance of said combustible gas and driving a gas turbine-electrical generator combination with the combusted gas.

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MORRIS O. WOLK, Primary Examiner
 R. E. SERWIN, Assistant Examiner

U.S. Cl. X.R.

48—197 R

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,817,724 Dated June 18, 1974

Inventor(s) JOHN R. B. ELLIS and FREDERICK C. FRANKLIN

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 4, line 54, "34,844" should read --34,834, now U.S. Patent 3,759,677.--

Col. 8, line 19, after the words "essentially no" and before "oxygen" insert --molecular--.

Signed and sealed this 4th day of February 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents