GASIFICATION MATERIAL COMBUSTION METHOD AND APPARATUS

ABSTRACT: A material combustion method and apparatus is disclosed wherein pyrolysis or volatilization, oxidation of solid carbonaceous char remaining after volatilization and oxidation of the gaseous products from volatilization are accomplished in separate locations. A combustion assembly is disclosed including a fluid bed pyrolyzer located over a vortex char combustion chamber. The gas phase oxidation can be in the combustors of a gas turbine.
FIG. 5

FROM COMPRESSOR
REFUSE
PARTICLE SEPARATORS
DANCING
70
VOLATILIZING
OXIDIZING CARBON
WATER
COMPRESSOR BLEED AIR
ASH

FIG. 6

FUEL GAS
SOLID PARTICLE RETURN
REFUSE
VOLATILIZING BED
COURSE ASH
FINE ASH
CARBON BED
WATER
COMPRESSOR BLEED AIR
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GASIFICATION MATERIAL COMBUSTION METHOD AND APPARATUS

The invention described herein was made in the course of or under a contract with the Department of Health, Education and Welfare.

The present invention relates in general to a material combustion method and apparatus and particularly to a gasification method and apparatus.

Broadly stated, the present invention is directed to a material combustion method and apparatus wherein in pyrolysis or volatilization, oxidation of the gaseous products produced in volatilization, and combustion of the carbonaceous char produced in the volatilization are accomplished in separate locations.

This method and apparatus provides a system wherein materials, such as solid waste and the like, can be substantially entirely disposed of efficiently and economically. This invention enables the efficient utilization of the energy from the waste materials.

In accordance with one aspect of the present invention, a material disposal apparatus is provided with a char combustion chamber, a pyrolyzer chamber positioned above the char combustion chamber for receiving material for combustion and means for conveying char products material produced in the pyrolyzer into the char combustion chamber and for conducting gaseous combustion products from the char combustion chamber into the pyrolyzer.

With this structure, the pyrolyzer provides the char for combustion in the combustion chamber and the combustion chamber produces the hot inert gases for pyrolysis of the waste material in the pyrolyzer. An additional feature and advantage of this structure lies in the fact that the heavier objects will settle to the bottom of the pyrolyzer chamber where they are subjected to the hottest inert gas introduced therein for pyrolysis.

In accordance with still another aspect of the present invention, the pyrolyzer is constructed in the form of a fluid bed reactor. This construction provides a unique cooperative process for the volatilization of materials while leaving a minute particular char which can then be utilized for generation of the inert gases.

In accordance with still another aspect of the present invention, the char combustion chamber is substantially cylindrical and includes means for introducing combustion gas thereinto substantially tangential to the cylinder walls to create a vortex therein and a throat is provided between the char combustion chamber and the pyrolyzer chamber. In accordance with this construction, char particles can be injected into the char combustion chamber, such as in the combustion gases, and retained in the vortex for subjection to substantial oxidation. The lower density, high temperature inert gases flow to the center of the vortex and are able to pass through the throat into the pyrolyzer chamber.

In accordance with still another aspect of the present invention, the pyrolyzer is located in a position above a vortex-type char combustor and includes a downwardly directed conical support screen for the particle fluid bed. In accordance with this aspect of the present invention, the heavier non-volatilizable materials in the waste being consumed will settle to the apex of the conical section where they are subjected to the hottest inert gases conducted into the pyrolyzer. If the materials are non-vaporizable, they will then be melted by the excessive heat of the inert gases and fall through the char combustion chamber axially of the vortex.

Other objects and advantages of the invention will become apparent when reading the following description and referring to the drawings in which like reference numbers represent corresponding parts in each of the several views.

In the drawings:

FIG. 1 is a schematic flow diagram of a waste disposal system and illustrates the operation of several different aspects of the present invention;

FIG. 2 is an enlarged schematic elevational view illustrating a gasifier in accordance with the present invention;

FIG. 3 is a plan view of a waste disposal system utilizing the present invention;

FIG. 4 is an elevational view, partially in section, of the embodiment illustrated in FIG. 3;

FIGS. 5 and 6 are elevational schematic views illustrating alternative gasifier systems utilizing with the present invention.

While the present invention is utilisable for consumption of a variety of materials in a variety of processes, it is particularly adaptable for use in a solid waste disposal system. Therefore, by way of illustrative example, the present invention will be described with reference to use in such a solid waste disposal system.

Referring now to the drawings, there is shown in schematic form a solid waste disposal system and different utilizations thereof. As schematically illustrated, the solid waste disposal system utilizes a waste receiving and storage assembly A in accordance with the present invention, a shredding assembly B, a drying assembly C, a compressor-turbine assembly D, a combustion assembly E, and an electric generator assembly F.

The solids wastes are typically received from municipal collection trucks 10 which dump the waste into the receiving and storage assembly A which includes a circular turntable or carousel 11 floating on a pond of water 13 within a hollow cylindrical housing 12 with suspended glass cloth panels 14 permitting truck access to the carousel and with the carousel rotatable to feed the solid wastes W into the shredding assembly B. The carousel 11 can be raised and lowered to assist refuse dumping and feeding operations by adjusting the level of pond 13 thereby eliminating the need for a crane and associated high-bay construction in the solid waste storage area. A large effective tipping area for the collection trucks 10 is provided by the circular shape of the carousel 11 and the panels 14 screen off the storage area while permitting an inflow of fresh air.

The solid wastes W are directed by a fixed leveling blade 15 over the carousel 11 into conveyors or a chute 16. The turntable elevation and the rotational speed can be controlled automatically or remotely controlled by an operator in the central control room of the waste disposal plant where the operator observes the carousel operation by closed circuit elevation.

In the shredding assembly B, all of the solid wastes are shredded to form a more nearly homogeneous shredded material W, which is easily transported through the remainder of the system by conventional automated devices for materials handling. The shredded solid wastes W are dried in the drying assembly C to increase the burning rate of waste in the overall system and eliminate the variability in burning rate resulting from widely different moisture contents. The heat utilized in the drying assembly C is provided by a heated air stream 18 which obtains its heat from a portion of the exhaust gases 19 from the gas turbine assembly D.

The compressor-turbine assembly draws at least a portion of its compressor intake air 21 through a filter 22 from the air space above the waste in the receiving and storing, shredding and drying assemblies. A, B, C, respectively, to prevent dust and odors from escaping to the environment. The shredded and dried solid waste W is transported via a conduit 23 and fed into the high pressure environment of the combustion chamber assembly E such as by a rotary feeder 24.

In the compression portion 20 thereof the compressor-turbine assembly D compresses the intake air 21 from the other assemblies and from the outside environment for use in the turbine combustors. Some of this compressed air is ducted via conduit 25 to the combustion assembly E to provide oxygen for combustion.

In the combustion chamber assembly E, to be described in greater detail below, the shredded dried waste W is broken down to provide fuel gas to be conveyed via conduit
The hot gases leaving the particle collectors 36 are expanded through the expansion and drive portion 37 of the compressor-turbine assembly D which drive the compressor portion 20 of the assembly D, and drives the electric generator assembly F to produce electric power.

The hot gas leaving the compressor-turbine assembly D is near atmospheric pressure but at elevated temperature so that the portion 19 can be utilized for drying shelled solids waste material in the drying assembly C as described above. If the host material has a moisture content of 20% and this moisture is boiled out in the dryer, the exhaust gases need be recirculated. An optional exhaust heat recovery boiler 38 can be provided in the exhaust line from the gas turbine for utilization of the heat for producing steam for heating, air conditioning, or desalting water. The hot exhaust gas is decelerated in an enlarged exhaust plenum and released to the atmosphere from a large area in the roof of the plant.

Use of the gas turbine cycle for waste collection allows performance of many services to the community besides incineration of solid wastes. For example, the capability of the gas turbine-combustor can be utilized to draw a powerful vacuum and suck the solid waste through underground pipes and deposit this waste in the carousel for combination in the disposal system. Alternatively, the exhaust heat from the gas turbine can be utilized to produce fresh water daily from saline or brackish water. Still further, the disposal system can be utilized to incinerate the sewage sludge resultant from sewage systems.

The combustion of hydrocarbon materials principally found in solid waste occurs in three distinct phases and these phases occur almost independently in all combustion processes. In the first phase, called pyrolysis or volatilization, the material is heated, causing decomposition of the hydrocarbon solids into hydrocarbon gases; these gases are oxidized in a gas phase reaction; and finally, the solid carbonaceous char remaining after volatilization is oxidized. In accordance with the present invention, the combustion of the waste material can be accomplished in cooperation with a combustion chamber such as the combustors of a gas turbine by a gasification method and apparatus as illustrated in FIGS. 1, 2, 5 and 6 taking advantage of the distinctions between these phases.

First, with reference to FIGS. 1 and 2, in the gasifier concept of the present invention, each of these phases occurs in a separate location. The shredded and dried solid waste material W is first injected into a conduit 50 into a pyrolyzer or pyrolyzing chamber 51 where the first phase pyrolysis or volatilization takes place. The combustible gases generated in the pyrolyzing chamber 51 serve as a gaseous fuel for the gas turbine where the gas phase oxidation occurs in the gas turbine combustors 53. Hot inert gases are also injected into the pyrolyzer for pyrolyzing the solid wastes. These hot inert gases are separately generated in a char combustion chamber 52 which for the third phase oxidizes the residual solid char coming from the pyrolyzer with air bled from the compressor portion 19 of the gas turbine assembly D. The bleed air that is directed into the char combustion chamber 52 from the gas turbine compressor is compressed in a supercharger 54 (approximately 5% of the gas turbine flow rate) to account for pressure losses in both the char combustion chamber 52 and the pyrolyzing chamber 51.

The purpose of the pyrolyzer is to chemically decompose, or pyrolyze, the incoming solid wastes. Pyrolysis is accomplished by heating in an oxygen-free environment and if necessary heat is derived from hot inert gases (over 3000°F.) supplied to the pyrolyzer 51 from the char combustion 52. In the embodiment of the gasifier system illustrated, the pyrolyzer 51 includes a fluid bed reactor of inert particles 55 such as sand supported on a downwardly directed conical, porous injector plate 56 apertured at the conical apex. This bed of particles 32 is initially heated by an external source (not shown) to an elevated temperature for vaporization of waste material and operation is maintained with the compressed hot gases from the char combustion chamber 52. Abrasion by the fluid bed will rapidly remove char as it is formed on the surface of waste material and this fine char material thus abraded will be carried out of the fluid bed by gases and subsequently separated by particle collectors 36.

The primary constituent of the organic fraction of the solid waste material is cellulose, the chief component of all wood and plant fibers, and hence of all paper products. In the fluid bed 55 in the pyrolyzing chamber 51, degradation of the cellulose material will occur and eventually all the oxygen and hydrogen, and a substantial part of the carbon, will be driven off leaving a carbonaceous char and non-degradable components such as metal and glass. Most of the carbon driven off is in the form of fine particles produced by the abrading action of the particle bed. Oxidation of this fixed carbon particle in the pyrolyzer 51 could not be accomplished without burning some of the fuel gases. Therefore, in accordance with this aspect of the present invention, this char particulate is removed from the pyrolyzer and returned via a conduit 58 to the char combustor 52 where it is burned at near stoichiometric fuel air ratios for generation of the inert gases for the pyrolyzer 51.

One construction for the char combustor 52 in accordance with the present invention and as illustrated in FIG. 2 is a vortex combustor consisting of a cylindrical housing 57 with a ceramic lining and into which compressor air with entrained fine char particles recovered from the pyrolyzer gases by the particle collectors 36 via conduit 58 is introduced tangentially via a conduit 59 at high velocity such as 300 feet per second causing gases in the combustor chamber 52 to flow in free vortex motion. Centrifugal force causes solid particles entrained in the vortex to continue to rotate until consumed or slowed by contact with the walls while the inert gases increase in angular velocity and are removed from the core of the vortex and pass through a re-entrant throat section 61 and the ceramic injector plate 56 into the fluid bed pyrolyzer 51. Since the temperature in the combustor is above 3000°F., the ash and metals are melted and these molten droplets collect on the wall of the chamber. Larger particles stick to the molten ash and are exposed to a relatively high velocity air stream promoting rapid combustion. The liquid ash and metal subsequently drain through a hole 62 in the bottom of the char combustor 52 into a quench tank 63. The molten residue is suddenly quenched and solidified resulting in the formation of granular residue which is removed as a water slurry.

As described above the hot inert gases from the combustor 52 fluidize the particle bed 55 and volatilize combustible materials therein. Large pieces of solid waste that are not buoyed up by the fluid bed 55 migrate to the apex of the conical injector 56. There, these pieces are continuously exposed to the entering 3000°F. gas stream from the combustor 52 and rapidly are either pyrolyzed or melted. If melted, the molten residue drips directly into the quench tank 63 through the core of the vortex combustor chamber 52.

The hot gases leaving the fluid bed 52 entrain many ash particles which must be removed such as by the particle collectors 36 before the gases are allowed to enter the turbine. Large particulate matter, if allowed to pass through the turbine, will damage the turbine severely. Gas cleaning by the particle collectors 36 is accomplished for the turbine also satisfies the clean air requirements for exhaust gases. The particle collectors can take a number of different forms such as inertial separators, electrostatic precipitators and mist filters. The particle collectors 36 schematically illustrated should be in the embodiment of inertial separators followed by electrostatic precipitators. The inertial separators remove all but the smallest particles, and these small particles are removed by the electrostatic precipitators.

Inertial separators use centrifugal force to separate particles from the gas stream and can provide efficiencies of 97.8% and greater for particles as small as 10 microns in
The high temperature of the fuel gas going from the pyrolyzer 51 to the gas turbine combustors 53 will assist rapid, complete combustion, and since only this high temperature gaseous fuel is combusted, it becomes unnecessary to use a high core temperature combustor thereby avoiding generation of the usual nitrogen oxides and promoting uniform temperature profile in the combustor.

The gasifier combustion method and apparatus of FIGS. 1 and 2 operates exceptionally well to avoid air pollution. For example, SO₂ and HCl are removed in the fluid bed pyrolyzer 51 by reaction with basic ash materials such as CaO and MgO. Limestone or dolomite can be added to the pyrolyzer bed to aid this reaction. However, in most cases sufficient CaO and MgO already exist in the solid waste ash. Furthermore, nitrogen-oxygen compounds will not be generated in the pyrolyzer chamber 51 since practically no oxygen is present.

An integrated gasifier in accordance with this construction approximately 4 feet in diameter and 20 feet high will process 200 tons of solid waste (refuse) material in 24 hours. Existing gasifiers such as the General Electric G5191 heavy duty industrial gas turbine or the Pratt and Whitney ST4A-8 gas turbine can be utilized.

Other combustion apparatus besides that illustrated in FIGS. 1 and 2 can be utilized with the present invention. By way of example, a simple gravity feed gasifier schematically illustrated in FIG. 5 can be utilized. In this construction, solid wastes are introduced at the top of a volatilizing chamber and fed by gravity as they are volatilized and burned to ash, which is removed continuously from the bottom. Air is directed up through the gasifier 70 after being introduced into the ash region and the air velocities are low to preclude agitation of the pyrolyzing products. After passing through the ash, the air reaches the carbon combustion zone where the carbon is combined with a limited supply of oxygen to form carbon monoxide. Water is also introduced and the resultant steam and hot carbon result in the "producer gas" reaction which yields hydrogen and carbon monoxide and absorbs heat. The flow rates of water and air are controlled such that all the carbon is consumed, while assuring that slagging temperatures are not reached. The hot gases rising from the carbon combustion zone furnish heat to pyrolyze or volatilize the incoming solid waste, thereby generating the fuel gas which is ducted into the gas turbine combustors for final combustion with the primary air flow coming from the turbine compressor.

Another combustion method and apparatus is schematically illustrated in FIG. 6 and consists of a dual fluid bed gasifier 80. In the dual bed the oxygen necessary to combust the carbon is separated from the initial pyrolysis process. Solid wastes are introduced into the upper or volatilizing fluid bed where they are pyrolyzed by hot inert gases coming from the carbon combustion fluid bed. Rapid, uniform pyrolysis is assured by the highly stirred conditions existing in the fluid bed. The fuel gas resulting from the pyrolysis passes through particle collectors on its way to the gas turbine combustor. The products collected contain both ash and carbonaceous char generated by the pyrolysis process. This char is burned by introducing the particles into the second or carbon combustion fluid bed and fine ash is separated from the second bed affluent by a second set of particle collectors. Ash slagging temperatures are prevented in the carbon bed by limiting the available oxygen and by introducing water or steam.

While the present invention is ideally suited for combustion of solid waste in a waste disposal plant utilizing a gas turbine, it is ideally suited for operation in combination with a commercial gas turbine whereby the gas turbine can be run with materials such as Bunker C. coal, and other low grade fuels normally unsuitable for burning in a gas turbine.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it is understood that certain changes and modifications may be practiced within the spirit of the invention as limited only by the scope of the appended claims.

We claim:

1. A material combustion assembly comprising, in combination, a char combustion chamber, means for directing a combustion gas into said char combustion chamber, a pyrolyzer chamber, means for directing combustibles into said pyrolyzer, means for conveying charred material produced in said pyrolyzer into said combustion chamber and for conducting gaseous combustion products from said char combustion chamber into said pyrolyzer.

2. The material combustion assembly in accordance with claim 1 wherein said pyrolyzer chamber is positioned above said char combustion chamber and said conveying and directing means includes a throat positioned between said pyrolyzer chamber and said combustion chamber.

3. The material combustion assembly in accordance with claim 1 wherein said pyrolyzer chamber is positioned above said char combustion chamber and includes downwardly directed conical walls means for passing inert gases from said char combustion chamber into said pyrolyzer and molten material from said pyrolyzer centrally through said char combustion chamber.

4. The material combustion assembly in accordance with claim 2 and wherein said combustion gas directing means includes means for introducing combustion gas substantially tangential to the chamber walls of said char combustion chamber to cause gases in said combustion chamber to flow in a vortex.

5. The material combustion assembly in accordance with claim 2 including means for collecting and removing residual combustible material at the bottom of said char combustion chamber.

6. The material combustion assembly in accordance with claim 2 wherein said pyrolyzer includes a mass of incombusible particles of a size for fluid suspension of gaseous products directed into said pyrolyzer from said char combustion chamber.

7. The material combustion assembly in accordance with claim 6 including a provision to position said throat and said fluid material for passing hot inert gas into said pyrolyzer and molten material from said pyrolyzer to said char combustion chamber.

8. Waste disposal apparatus comprising, in combination, a gas turbine for compressing and directing air to a turbine combustion chamber, a char combustion chamber, means for directing a portion of the compressed air from said gas turbine to said char combustion chamber, a pyrolyzer
chamber positioned above said char combustion chamber, means for directing combustibles into said pyrolyzer chamber, means for conveying char produced in said pyrolyzer into said char combustion chamber and for directing gaseous combustion products from said pyrolyzer chamber to the combustion chambers of said gas turbine, and including downwardly directed wall means for passing inert gases from said char combustion chamber into said pyrolyzer chamber and molten material from said pyrolyzer chamber centrally through said char combustion chamber.

9. The material combustion assembly in accordance with claim 8 and wherein said combustion gas directing means includes means for introducing combustion gas substantially tangential to the chamber walls of said char combustion chamber to cause gases in said combustion chamber to flow in a vortex.

10. The method of consuming material comprising the steps of compressing air, directing the air to a char combustion zone, burning char in the char combustion zone, directing exhaust inert gas from the char combustion zone to a pyrolyzing zone, volatilizing the material in the pyrolyzing zone, directing char from the pyrolyzing zone to the char combustion zone, directing the exhaust gases from the pyrolyzing zone to a combustion zone, and burning the exhaust gases from the pyrolyzing zone in the combustion zone.

11. The method of claim 10 including the step of removing particulate matter from the exhaust gases from the pyrolyzing zone.

12. The method of claim 10 wherein said compressed air is directed into the char combustion zone to form a vortex and said burning step is performed in a vortex.

13. The method of claim 12 including passing molten incombustibles from the pyrolyzing zone through the center of the vortex.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,540,388 Dated November 17, 1970

Inventor(s) Richard D. Smith et al.

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

On the cover sheet the illustrative drawing should appear as shown below:

Signed and sealed this 18th day of January 1972.

(SEAL)
Attest:
Edward M. Fletcher, Jr. Robert Gottschalk
Attesting Officer Acting Commissioner of Patents