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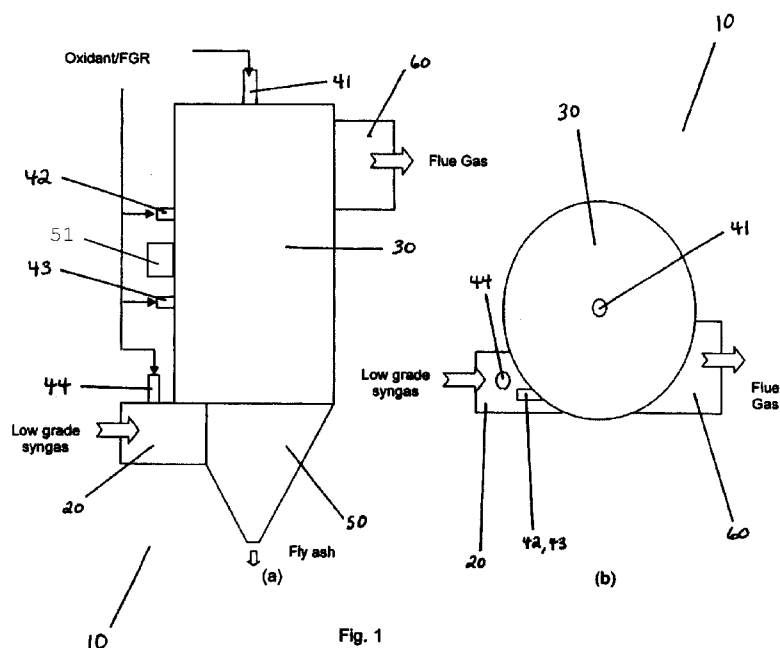


Fig. 1

(57) Abstract: Systems and methods for effectively combusting municipal waste are disclosed. Aspects of the present invention provide improved techniques for increasing efficiency of combusting municipal waste as well as decreasing emission of harmful gases. In one aspect of the present invention a system is provided which includes a post combustor for combusting gasified waste. In another aspect of the present invention, a method for using the post combustor to gasify the waste is provided.

SYSTEM AND METHOD FOR GASIFICATION-COMBUSTION PROCESS USING POST COMBUSTOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority to US Provisional Application 61/080,805, filed July 15, 2008 and US Patent Application 12/467,887, filed May 18, 2009, the disclosure of which is incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present invention relates to a system and method for implementing a gasification-combustion process that converts waste or solid fuel into energy, while producing a minimal amount of undesirable emissions.

BACKGROUND

[0003] Municipal solid waste ("MSW") is the gross product collected and processed by municipalities and governments. MSW includes durable and non-durable goods, containers and packaging, food and yard wastes, as well as miscellaneous inorganic wastes from residential, commercial, and industrial sources. Examples include newsprint, appliances, clothing, scrap food, containers and packaging, disposable diapers, plastics of all sort including disposable tableware and foamed packaging materials, rubber and wood products, potting soil, yard trimmings and consumer electronics, as part of an open-ended list of disposable or throw-away products. A traditional method of waste disposal is a landfill, which is still a common practice in some areas. Many local authorities, however, have found it difficult to establish new landfills. In those areas, the solid waste must be transported for disposal, making it more expensive.

[0004] As an alternative to landfills, a substantial amount of MSW may be disposed of by combustion at a municipal solid waste combustor ("MWC"), which is also known as a waste-to-energy plant ("WTE"). The typical MWC has a moving grate that enables the movement of waste through the combustion chamber and thus allows complete combustion of the waste. The MWC usually includes a primary air source and a secondary air source. Primary air is supplied from under the grate and is forced through the grate to sequentially dry (evolve water), de-volatilize (evolve volatile hydrocarbons), and burn out (oxidize nonvolatile hydrocarbons) the waste bed. The quantity of primary air is typically adjusted to maximize burn out of the carbonaceous materials in the waste

bed, without having any excess air. Secondary air is supplied through nozzles located above the grate and is used to create turbulent mixing that destroys the hydrocarbons that evolved from the waste bed. The total amount of air (primary and secondary) used in a typical MWC is approximately 60% to 100% more than the amount of air required to achieve stoichiometric conditions (i.e., the theoretical conditions under which a fuel is completely burned).

[0005] One of the problems associated with the conventional combustion of MSW and other solid fuels is that it creates undesirable and harmful byproducts, such as NO_x, carbon monoxide, and dioxins. For example, NO_x is formed during combustion through two primary mechanisms. First, fuel NO_x is formed by the oxidation of organically bound nitrogen (N) found in MSW and other fuels. When the amount of O₂ in the combustion chamber is low, N₂ is the predominant reaction product. However, when a substantial amount of O₂ is available, an increased portion of the fuel-bound N is converted to NO_x. Second, thermal NO_x is formed by the oxidation of atmospheric N₂ at high temperatures. Because of the high activation energy required, thermal NO_x formation does not become significant until flame temperatures reach 1,100°C (2,000°F).

[0006] There are several known technologies for reducing the harmful emissions created by conventional MSW combustion systems. For example, there are two groups of technologies known to control NO_x emissions: combustion controls and post-combustion controls. Combustion controls limit the formation of NO_x during the combustion process by reducing the availability of O₂ within the flame and by lowering combustion zone temperatures. Post-combustion controls involve the removal of the NO_x emissions produced during the combustion process (e.g., selective non-catalytic reduction (SNCR) systems and selective catalytic reduction (SCR) systems).

[0007] Despite the improvements made in reducing the harmful emissions of conventional combustion systems, there is still a need for alternative methods and systems that efficiently convert MSW or other solid fuels to energy while producing a minimal amount of undesirable emissions.

SUMMARY OF THE INVENTION

[0008] The present invention relates to a gasification-combustion system and method that converts waste or other solid fuels to energy while producing significantly lower quantities of NO_x, carbon monoxide, dioxins, and other undesirable emissions than

conventional mass combustion. Gasification is the partial combustion of a solid fuel that produces a gas mixture. The gasifier of the present invention operates at lower temperatures and introduces less air than conventional combustion systems, and thus it produces a lower amount of undesirable emissions. According to the present invention, a post combustor uses the gas mixture produced by the gasifier to generate thermal energy. The post combustor controls combustion of the gas mixture using adjustable injection nozzles. The nozzles can be adjusted based on the composition of the specific gas mixture entering the post combustor, so as to achieve optimal combustion conditions with minimal emissions. In sum, the gasification-combustion process using the post combustor of the present invention significantly reduces the amount of undesirable emissions produced when converting waste or solid fuel to energy. The above-described method and system is just one example of the present invention, which can vary in other embodiments.

[0009] For example, in one configuration of the present invention, a system for gasifying and combusting waste is provided. The system may contain a gasifier for mixing syngas with air or recirculated flue gas; said gasifier may contain an entrance duct and a premixing nozzle designed to inject the air or recirculated flue gas into the gasifier. The system may also contain a post combustor. The post combustor may contain an entrance duct for receiving syngas from the gasifier; a cyclone-shaped chamber positioned near the end of the entrance duct designed to collect fly ash or heavy weight particles; a top injection nozzle for directing air to flow through the post combustor into the cyclone shaped chamber; tangential nozzles for directing air or recirculated flue gas into the post combustor; sensors for measuring temperature, moisture, and carbon dioxide; a controller for positioning and controlling the nozzles to make air flow and temperature more uniform in the post combustor; and an exit duct for allowing gas to leave the post combustor. In some embodiments the top injection nozzle may be positioned so that the air flowing through the nozzle forces fly ash or heavy weight particles into the cyclone-shaped chamber; the tangential nozzles may have a direction and a position; and/or the controller may rely upon information from the sensors to determine the direction and position of the tangential nozzles.

[0010] Another configuration of the present invention sets forth a method for gasifying and combusting waste. The method may comprise one or more of the following steps: mixing syngas with air or recirculated flue gas in a gasifier; receiving the syngas from the gasifier at a post combustor; collecting fly ash or heavy particles with a cyclone-

shaped chamber; directing air to flow through the post combustor into the cyclone shaped chamber; directing air or recirculated flue gas into the post combustor; using a sensor to gather measurements relating to temperature, moisture, and carbon dioxide of gas inside the post combustor; analyzing these measurements for determining which direction and position tangential nozzles connected to the post combustor should face; adjusting the tangential nozzles so that they face the determined direction and position; and/or allowing gas to leave the post combustor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings, which are included to provide further understanding of the invention and are incorporated in and constitute part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention. In the drawings:

[0012] FIG. 1(a) is a side schematic view of an embodiment of the post combustor used in the gasification-combustion process of the present invention.

[0013] FIG. 1(b) is a top schematic view of an embodiment of the post combustor used in the gasification-combustion process of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. Throughout the following drawings, like numerals indicate like elements.

[0015] The present invention relates to a system and method that converts MSW or other solid fuels into energy while producing a reduced amount of undesirable emissions. The first step of the present invention, gasification, involves the partial combustion of a solid fuel. The second step, combustion, involves using the gas mixture produced during gasification to generate thermal energy. Both steps of the gasification-combustion process, and the apparatuses used to perform them, will be described in detail below.

[0016] Gasification is the partial combustion of MSW or other solid fuels. It results in the production of a gas mixture of hydrogen, carbon monoxide, carbon dioxide, and water vapor, known as syngas. Gasification of solid fuel has several advantages over the conventional process of complete combustion. First, complete combustion generally requires mixing the fuel with air in excess of the amount needed to achieve stoichiometric

conditions (i.e., the ideal conditions in which fuel is completely burned). The high amount of oxygen present during complete combustion facilitates the production of harmful gases, such as NO_x and dioxins. In contrast, gasification involves only partial combustion, and, as a result, it requires significantly less air than complete combustion. More specifically, the gasifier of the present invention can perform gasification of a solid fuel using a sub-stoichiometric amount of air. There are several benefits to the reduction in air that is achieved by using gasification. Introducing less oxygen means that a lower amount of NO_x and dioxins is produced by the solid fuel. In addition, the fuel bound nitrogen, which would normally bond with excess oxygen to form NO_x, is more likely to form ammonia or hydrogen cyanide. This is significant because, as described in detail below, the syngas formed during gasification is subsequently combusted using a post combustor. During this subsequent combustion, the ammonia and hydrogen cyanide react with and decompose some of the NO_x that is generated by combustion of syngas. And, lastly, using less air reduces the costs associated with operating a combustion system.

[0017] Furthermore, the gasifier of the present invention is designed to operate at significantly lower temperatures than a conventional combustion system. In a preferred embodiment, the gasifier operates at temperatures below the melting temperature of ash. This is significant because the combustion of solid fuel produces both bottom ash and fly ash. When a combustion system operates at high temperatures, the ash can melt and cause slag formation on the moving grate components, which may require substantial maintenance. Thus, by sustaining an operating temperature below the melting point of ash, the gasifier of the present invention limits the potential for slagging. This reduces the overall maintenance costs associated with converting waste or solid fuel to energy and makes its more practical to use conventional moving grate technology. The low temperature gasification of solid fuel is also advantageous because it produces less particulate emissions and noxious gases, such as NO_x, than conventional high temperature combustion.

[0018] According to the present invention, the syngas produced during gasification flows out of the gasifier and into a post combustor, where the syngas undergoes combustion. The post combustor subjects the syngas to turbulent air flow that is only slightly in excess of stoichiometric conditions (and thus still less than the amount of air used in conventional combustion systems). The post combustor operates at higher temperatures than the gasifier, which has the effect of reducing carbon monoxide

emissions and destroying most of the dioxins formed during gasification. In addition, the amount of excess air present in the post combustor is minimal, which, along with the ammonia and hydrogen cyanide formed during gasification, reduces the amount of NO_x generated by combustion of the syngas. In a preferred embodiment of the present invention, the syngas is resident in the combustion chamber of the post combustor for longer than two seconds and the operating temperature is greater than 800°C. The thermal energy created by combustion of the syngas can be used in a variety of ways, such as to produce steam and generate electricity. In sum, the gasification-combustion process of the present invention can convert MSW or other solid fuel into energy while generating significantly lower emissions of carbon monoxide, NO_x, and other organics such as dioxins than the conventional process of complete combustion.

[0019] FIGS. 1(a) and 1(b) show preferred embodiments of the post combustor 10 used in the gasification-combustion process of the present invention. As can be seen in FIG. 1(a), the syngas generated by the gasifier flows into the post combustor 10 through an entrance duct 20. Prior to entering the combustion chamber 30 of the post combustor 10, the syngas is premixed with air, flue gas recirculation (FGR), or another oxidant such as plasma that is injected into the entrance duct 20 via premixing nozzle 44. Premixing the syngas with an oxidant allows the combustion of the syngas to occur at a lower temperature than it would without such premixing. This is significant because maintaining a lower combustion temperature reduces the production of NO_x.

[0020] The post combustor 10 is designed so that there is a cyclone shaped chamber 50 at the end of the entrance duct 20, where the syngas enters the combustion chamber 30. The cyclone shaped chamber 50 is used to collect fly ash or heavy weight particles that are created during gasification or combustion. The cyclone shaped chamber 50 is aided by the downward flow of air from the top injection nozzle 41. The downward air flow forces fly ash and other heavy weight particles downward into the cyclone shaped chamber 50, while allowing the syngas to enter the combustion chamber 30. The fly ash and other particles can either concentrate in the center of cyclone shaped member 50 and flow downward, or form slag on the walls of the cyclone shaped member 50 and flow downward.

[0021] The combustion chamber 30 of post combustor 10 includes multiple nozzles for injecting air or another oxidant into the combustion chamber 30. As explained above, the top injection nozzle 41 is designed to inject air or another oxidant into the

combustion chamber 30 in a generally downward direction. Tangential injection nozzles 42 and 43 are configured to inject air or another oxidant tangentially into the combustion chamber 30 from desired angles. The present invention contemplates that additional nozzles can be provided so as to achieve the desired injection of air into the combustion chamber 30. The nozzles 41, 42, and 43 can be positioned and controlled by a controller 51 so that a uniform flow of air, as well as a uniform temperature, is maintained throughout the combustion chamber 30 during combustion of the syngas. This is important because temperature variations, and specifically pockets of higher temperatures, promote the creation of NO_x. Thus, by maintaining uniform air flow and temperature, the post combustor 10 of the present invention reduces the amount of NO_x generated during combustion.

[0022] In a preferred embodiment of the present invention, the post combustor 10 measures certain characteristics, such as the temperature, moisture, and carbon dioxide content, of the syngas as it enters the post combustor 10 from the gasifier. This information is then used to adjust the nozzles 41-44, so as to obtain optimal air flow and conditions for combustion of the specific type of syngas entering the combustion chamber 30. To obtain optimal conditions, the direction and amount of air flow from each nozzle 41-44 is adjusted individually and independently of one another. Computational fluid dynamics ("CFD") is used to determine exactly how the nozzles 41-44 should be adjusted in response to the measurements taken as the syngas enters the combustion chamber 30.

[0023] The post combustor 10 also includes an exit duct 60 that permits flue gas to leave the combustion chamber 30. As explained above, the flue gas can then be injected back into the combustion chamber 30 via the nozzles 41-44. This is known as flue gas recirculation ("FGR"). FGR lowers the amount of O₂ in the combustion chamber 30 and suppresses the temperature in the combustion chamber 30. As a result, FGR has the effect of reducing the amount of NO_x generated by combustion of the syngas.

[0024] While exemplary embodiments of the invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous insubstantial variations, changes, and substitutions will now be apparent to those skilled in the art without departing from the scope of the invention disclosed herein by the Applicants. Accordingly, it is intended that the invention be limited only by the spirit and scope of the claims, as they will be allowed.

[0025] It is hereby claimed.

CLAIMS

1. A system for gasifying and combusting waste comprising:
 - a. a gasifier for mixing syngas with air or recirculated flue gas; said gasifier containing an entrance duct and a premixing nozzle designed to inject the air or recirculated flue gas into the gasifier; and
 - b. a post combustor comprising:
 - i. an entrance duct for receiving syngas from the gasifier;
 - ii. a cyclone-shaped chamber positioned near the end of the entrance duct designed to collect fly ash or heavy weight particles;
 - iii. a top injection nozzle for directing air to flow through the post combustor into the cyclone shaped chamber;
 - iv. a tangential nozzle for directing air or recirculated flue gas into the post combustor;
 - v. a sensor for measuring temperature, moisture, or carbon dioxide; and
 - vi. a controller for positioning and controlling the tangential nozzle to make air flow and temperature more uniform in the post combustor.
2. The system of Claim 1 wherein the top injection nozzle is positioned so that the air flowing through the nozzle forces the fly ash or heavy weight particles into the cyclone-shaped chamber.
3. The system of Claim 1 wherein said tangential nozzle has a direction and a position; and said controller relies upon information from the sensor to determine the direction and position of the tangential nozzle.
4. The system of Claim 1 comprising an exit duct for allowing gas to leave the post combustor.
5. A method for gasifying and combusting waste comprising the following steps:
 - a. mixing syngas with air or recirculated flue gas in a gasifier;
 - b. receiving the syngas from the gasifier at a post combustor;
 - c. collecting fly ash or heavy particles with a cyclone-shaped chamber;
 - d. directing air to flow through the post combustor into the cyclone shaped chamber;
 - e. directing air or recirculated flue gas into the post combustor;

- f. using a sensor to gather measurements relating to temperature, moisture, and carbon dioxide of gas inside the post combustor;
 - g. analyzing these measurements for determining which direction and position a tangential nozzle connected to the post combustor should face;
 - h. adjusting the tangential nozzle so that it faces the determined direction and position.
- 6. The method of Claim 5 comprising the step of allowing gas to leave the post combustor.

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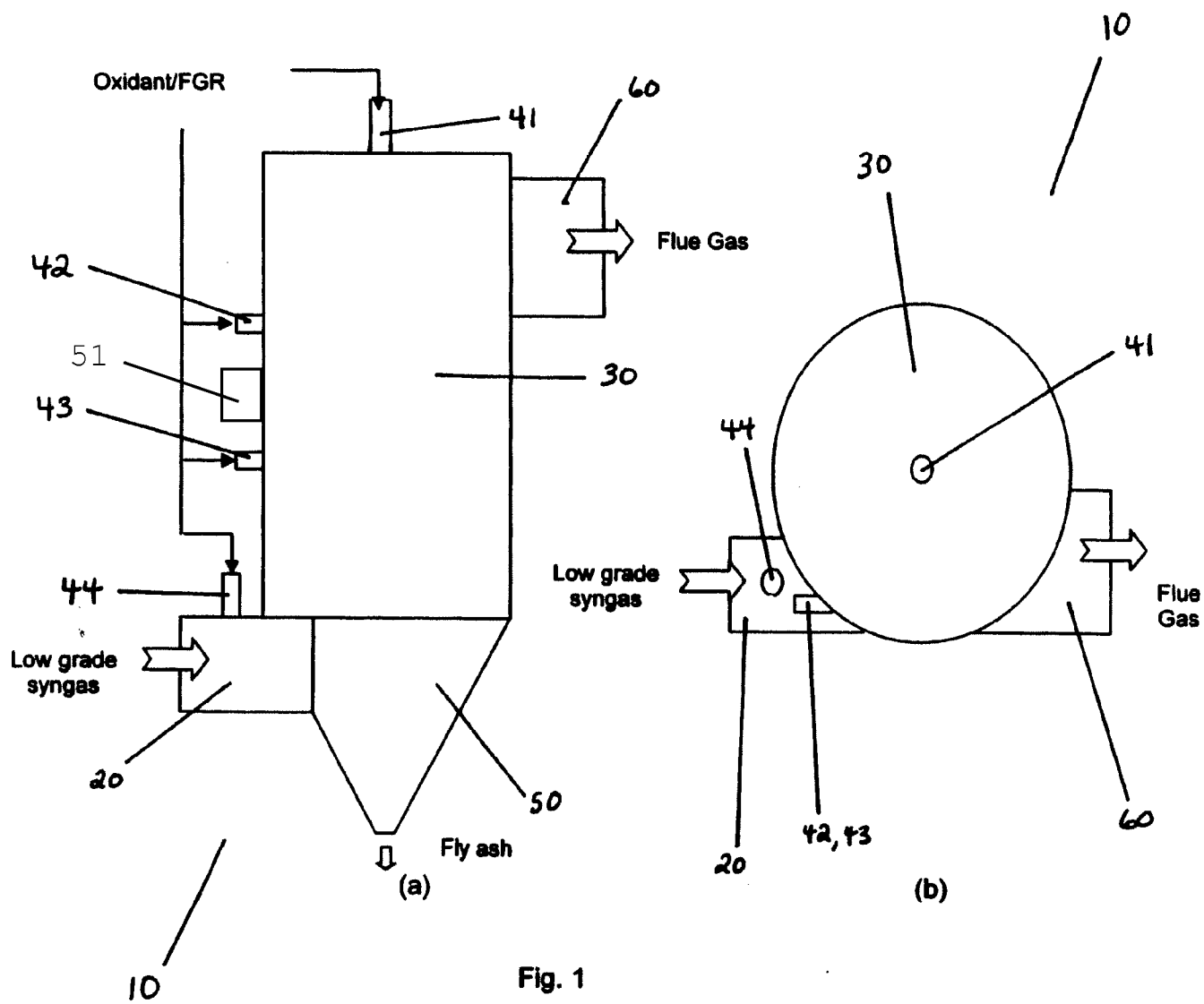


Fig. 1