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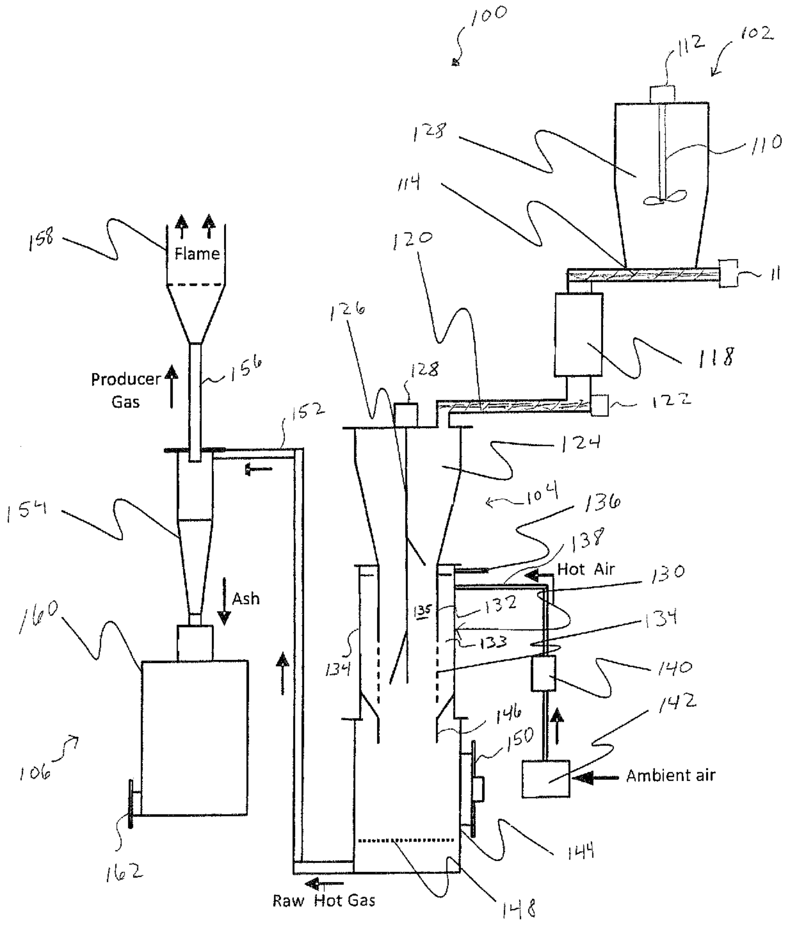
# (54) Title: DOWNDRAFT GASIFIER WITH INTERNAL CYCLONIC COMBUSTION CHAMBER



**(57) Abstract:** A downdraft gasifier is disclosed. The gasifier has a biomass feeding unit, a combustion chamber, and a separator unit. The biomass feeding unit accepts raw biomass materials and selectively feeds the materials into the combustion chamber. The combustion chamber provides means to induce pyrolysis, tar cracking, and char gasification of the raw biomass materials to produce gases and ash. The separator unit accepts the gases and ash from the combustion chamber and separates the gases from the ash.

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# DOWNDRAFT GASIFIER WITH INTERNAL CYCLONIC COMBUSTION CHAMBER

## FIELD OF THE INVENTION

This disclosure relates to gasification of biomass materials in general and, more specifically, to gasification by downdraft gasifiers.

## BACKGROUND OF THE INVENTION

Biomass may be converted into useful gas products such as carbon monoxide (CO), carbon dioxide ($CO_2$), hydrogen ($H_2$), and others. There are multiple processes by which the raw biomass materials may be gasified. These include pyrolysis, tar cracking, and char gasification. Heating the biomass material under the proper circumstances such that the desired gases are released without being oxidized or otherwise consumed is one commonality among certain of the various gasification methods.

In order to obtain useful quantities of gases from raw biomass material the gasification process must be implemented in such as way as to operate in a steady state. The desirable gases, or production gases, should more or less be output a steady rate. Improper handling and processing of the biomass can result in a suboptimal amount of the raw biomass being gasified. Unacceptably high levels of undesirables can also be produced and taint the output gasses if the production process is not controlled.

## SUMMARY OF THE INVENTION

The invention disclosed and claimed herein, in one aspect therof, comprises a downdraft gasifier. The gasifier has a biomass feeding unit, a combustion chamber, and a separator unit. The biomass feeding unit accepts raw biomass materials and selectively feeds the materials into the combustion chamber. The combustion chamber provides means to induce pyrolysis, tar cracking, and char gasification of the raw biomass materials to produce gases and ash. The separator unit accepts the gases and ash from the combustion chamber and separates the gases from the ash.

The means to induce pyrolysis, tar cracking, and char gasification may comprise a biomass chamber, a tar cracking chamber, and a char gasification chamber. The tar cracking chamber further may comprise substantially cylindrical inner and outer walls. The inner wall may have a plurality of perforations therein. The perforations may be selectively closable.

The means to induce pyrolysis, tar cracking, and char gasification may further comprises a stirrer operable to stir biomass in the combustion chamber through at least the biomass chamber and a portion of the tar cracking section. A heat source may also be included. The separation unit may include a cyclonic separator.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating one embodiment of a gasification system according to aspects of the present disclosure.

FIG. 2 is a schematic diagram illustrating one embodiment of a gasification combustion chamber for use with the gasification system of FIG. 1.

FIG. 3 illustrates an exemplary temperature profile of a downdraft gasifier constructed according to aspects of the present disclosure.

FIG. 4 illustrates the pressure over time of various output gases from a gasifier constructed according to aspects of the present disclosure.

FIG. 5 is a flow diagram illustrating an embodiment of a gasification process according to the present disclosure.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, a schematic diagram illustrating one embodiment of a gasification system according to aspects of the present disclosure is shown. The gasifier system **100** comprises three primary components: a biomass feeding unit **102**; a combustion chamber **104**; and a separator **106**. These primary components may further comprise a number of subcomponents, which will be described in detail below. The system **100** is operable to accept biomass as an input product and provide useful gases as an output product. The producer gas may be a mixture of carbon monoxide (CO), carbon dioxide ($CO_2$), hydrogen ($H_2$), and possibly other gases. In one embodiment, the gasification system **100** operates to convert biomass material into the desired gases by means of pyrolysis and tar cracking. This result may be achieved by creating high temperatures within the combustion chamber **104**. This causes the biomass material to break down into a number of materials, including ash and gases.

The biomass feeding unit **102** accepts the biomass intake product for processing by the system **100**. Biomass materials suitable for use with the system **100** may include, but are not limited to, woodchips, sewage or sludge, and refuse from the processing of plant matter. The gasification system may also operate using input biomass from plants grown with the specific purpose of being fed into the gasification system **100**.

The biomass feeding unit **102** comprises a hopper **108** and an agitator **110** with an agitator drive unit **112**. The dimensions and specific shape of the hopper **108** may vary in accordance with the needs of the end user. In the present embodiment, the hopper **108** has a tapered cylindrical shape. The agitator **110** may be a bladed or impellor type agitator or another type of agitator suitable for the biomass used with the gasification system **100**. It is also understood that stirrers, conveyors, or other implements could be used to ensure ready delivery of biomass material into the gasifier **100**. In the present embodiment where the agitator **110** is a rotational, the agitator drive unit **112** may be selected according to the duty cycle and torque requirements necessary to agitate the chosen biomass material. Some embodiments will provide a variable speed agitator. The agitator may be selectively operable such that it operates only when needed to insure proper feeding of the biomass.

In the present embodiment, a screw drive **114** serves to move biomass from the hopper **108** to an airlock **118**. In the present embodiment, a screw drive **114** is powered by a screw drive powering unit **116**. The screw drive powering unit **116** may be pneumatic, electrical, or powered by another source. The screw drive may be selectively operable and/or of variable speed so that feeding of the biomass may be properly controlled. In other embodiments, the screw drive **114** may be replaced with other conveyance means, such as conveyor belt, a slip stick movement device, or another suitable conveyance.

The air lock **118** serves to control the intake of biomass from the hopper 108 to the rest of the gasification system **100**. The air lock **118** also serves to prevent unwanted gases (e.g., air) from entering the combustion chamber **104**. Uncontrolled intake of ambient gasses may alter the desired chemical processes within the combustion chamber **104**. The airlock **118** may be electrically or mechanically powered. The airlock **118** or otherwise and may be remotely controllable, such as with an electronic relay, for example.

Beyond the air lock **118** is another screw drive **120**. The screw drive **120** is powered by another screw drive power unit **122**. These may be similar to the screw drive **114** and screw drive powering unit **116**. As before, in embodiments other than the one shown in FIG. 1, the screw drive **120**, as well as the screw drive powering unit **122,** could be replaced with other conveyance means. In some embodiments the airlock **118**, agitator **110**, and the screw drives **114**, **120** will operate in concert to ensure proper delivery of biomass to the combustion chamber **104**.

When the biomass material leaves the biomass feeding unit **102** it is fed into the combustion chamber **104**. The combustion chamber **104** provides a number of additional steps in the gasification process, which will be described in more detail below. A biomass section **124** may be provided near the top of the combustion chamber **104**. In one embodiment, the biomass section **124** serves to guide or direct the entering biomass material into the remainder of the combustion chamber **104**. The biomass section **124** may also be where the gasification process begins. High temperatures in the biomass section **124** may start an outgasing from the biomass material that will continue though the rest of the combustion chamber.

A stirrer **128** may be provided starting at the biomass section **124**. The stirrer may proceed further into the depths of combustion chamber **104**. The stirrer **126** may be made from a suitably heat resistant material able to withstand high temperatures necessary in the combustion chamber **104**. Blades or other agitating means may be provided on the stirrer **126**. The stirrer **126** is powered by a stirrer drive unit **128**. The stirrer drive unit may once again be electrical, pneumatic, mechanical or powered by another source. The biomass section **124** may be cylindrical, conical, or may have another shape. In one embodiment, the shape of the biomass section **124** serves to feed biomass material at the appropriate speed and volume down into a tar cracking section **130**.

The tar cracking section **130** may be generally cylindrical in shape and may provide an inner chamber **135**, defined by an inner cylindrical wall **132**. The inner wall **132** and an outer wall **134** may define an annular outer chamber **133**. It can be seen that the inner wall **132** may also feature perforations **134** that aid in the heating of the biomass material. As solid biomass in the inner chamber **135** is gasified, the gasses may escape the inner chamber **135** through the perforations **134** in the inner wall **132** into the annular chamber **133**.

It can be seen that in the embodiment shown the stirrer **126** proceeds at least part of the way through the inner chamber **135**. In this way, stirring or agitation is provided starting at the biomass section and proceeding through at least a portion of the tar cracking section **130**. This reduces and/or eliminates hot spots that would prevent efficient pyrolysis and tar cracking within the combustion chamber **104**.

In the present embodiment, the combustion chamber **104** is heated in part by the combustion of propane. The propane heating may only be necessary to start off the gasification process and may also serve to heat the biomass section **124**. In the present embodiment, propane enters through the fuel inlet **136** into the combustion chamber **104** where it may be ignited to produce heat. Although propane is used in the present example, it is understood that other fuel sources may be utilized, including but not limited to, natural gas, refined fuels, and other petroleum products.

It may important to carefully control oxygen content within the combustion chamber **104**. An air inlet **138** is provided for oxygenating the environment of the combustion chamber **104**. An additional function of the air inlet **138** may be to provide heated air for furthering the gasification processes of the system **100**. Some embodiments will provide a heater **140** for preheating the air entering the combustion chamber **104**. The heater **140** may be gas or electrical powered or, in some embodiments, may be based off of the waste heat generated by another outside process. In some embodiments, the heater **140** will preheat the air to up to 300°C or greater. A compressor **142** may also be provided for delivering the air into the combustion chamber **104** at the appropriate pressure. Pressurizing the ambient air will also heat the air to a certain degree, which may be useful in the gasification process. The compressor **142** can be electrical, pneumatic, or powered by another source. In the present embodiment, the heater **140** follows the compressor **142** resulting in higher efficiencies resultant from the heater **140** operating on compressed, and therefore hotter, air.

Various components of the system **100**, may be insulated for increased efficiency or productivity. For example, the air inlet **138** may be insulted. Similarly, all or a portion of the combustion chamber **104** may be insulated. In one embodiment, a ceramic wool blanket insulation (not shown) of about 25mm thickness will be utilized. In other embodiment, different materials that are suitably heat resilient may be utilized. Additionally, the thickness of any insulation used may be varied based upon a number of factors including the desired reaction temperature, the ambient air temperature, efficiency concerns, and others.

Below the tar cracking section **130** is a char gasification section **144**. In the present embodiment, the char gasification section **144** is separated from the tar cracking section by an annulus **146**. This component may be optional depending upon the nature of the biomass material being utilized. In the present embodiment, the annulus **146** serves to guide the partially gasified biomass into the char gasification section **144**.

The biomass material in the char gasification section **144** falls down onto a grating **148**. The grating **148** serves as a separation step to separate the solid material from the gases created in the combustion chamber **104**. It can be seen that the raw gases and ash are allowed to escape via a conduit **152** and travel to the separator **106**. The remaining solid biomass material will remain trapped by the grating **148** where additional char gasification will occur. As the biomass further gasifies, the ash and gasses produced will pass through the grating and out the conduit **152**.

It can be seen in FIG. 1 that the biomass section **124**, the tar cracking section **130**, and the char gasification section **144** may be arranged in a generally vertical fashion. The present embodiment provides the tar cracking section **130** in between the biomass section **124** and the char gasification section **130**. In this configuration, gravity may serve to feed the biomass through the combustion chamber resulting in down draft type gasification process. The combustion and gasification in the combustion chamber **104** may serve to create swirls, vortices, and other cyclonic gas flows. These may be controlled and/or aided by the stirrer **126** and perforations **133** in the inner chamber wall **132** of the tar cracking section **130**. This serves prevent cold spots in the combustion chamber **104**, particularly as the size of the process is scaled up.

The configuration of the combustion chamber **104** also helps to ensure substantially complete transformation of the biomass material into gases and ash. The gasses will include producer gas and possibly waste gas. The ashes will contain substantially no inorganic material. Nevertheless, as a practical consideration, means may be provided for clearing any solid material captured on the grating **148** that is not consumed by char gasification. In one embodiment, this may be an access portal **150** located near the grating **148** on the char gasification section **144** of the combustion chamber **104**. The access portal **150** may also allow for servicing, inspection, and/or replacement of the grating **148** and other components on the interior of the combustion chamber **104**.

The separation section **106** provides a separator **154** for separating the production gas from the ash in the raw gas stream coming from the conduit **152**. In one embodiment, the separator **154** is a cyclonic separator, but other separators may be utilized. The separator may be mechanical and may be electrically, pneumatically, or otherwise powered. The separated production gas is removed by the outlet **156**. The present embodiment illustrates a burner **158** that consumes the production gas coming from the outlet **156**. Thus, heat and other power may be provided for another process. However, it is understood that the production gas may be stored, utilized in a different manner, or further refined downstream of the gasification system **100**. A storage chamber **160** is provided for catching and/or holding the ash from the separator **154**. The ash may be useful in other processes and can therefore be retained until needed. In the present embodiment, an access portal **162** is provided for periodically removing the ash from the storage chamber **160**. It is understood, however, that other means may be utilized, such as conveyor belts or screw drives.

Referring now to FIG. 2, a schematic diagram illustrating one embodiment of a gasification combustion chamber for use with the gasification system of FIG. 1 is shown. FIG. 2 provides a more detailed view of another embodiment of the combustion chamber **104** for use with the gasification system shown in FIG. 1. It can be seen that the combustion chambers **200** and **104** are similar. Once again, a three-section embodiment is shown. The sections or chambers include the biomass section **124**, the tar cracking section **130**, and the char gasification section **144**. A stirrer **126** is provided, driven by a stirrer drive unit **128**. The fuel inlet **136** is shown, along with the air inlet **138**. A grating **148** is provided near the bottom end of the char gasification section **144**. Gases and ash escape through the gas conduit **152**. It will be appreciated that the combustion chamber **200** may be utilized in the gasification system **100** of FIG. 1, directly replacing the combustion chamber **104** illustrated in FIG. 1.

As has been described, in one embodiment biomass is provided to the combustion chamber **200** through a biomass feeding unit. Biomass enters the combustion chamber **200** through an inlet **202**. In FIG. 2, a biomass column **204** is illustrated to show one possible route for the biomass material through the combustion chamber **200**. It can be seen that the stirrer **126** may serve to stir the biomass **204**. As before, propane gas is introduced through the inlet **136**. In the present embodiment, the propane is supplied near the top of the tar cracking section **130**, and is used only for initial firing at start up of the process.

The tar cracking section **130** is once again formed by inner cylindrical walls **132** and an outer cylindrical wall **134**. An inner chamber **135** is bounded by the inner wall **132** and an annular chamber **136** is formed between the inner wall **132** and outer wall **134**. In the present embodiment, the entirety of the inner chamber **132** is provided with perforations **134**. Various degrees of perforation of the inner chamber **132** may be utilized depending upon the raw biomass material being utilized. Some embodiments may provide for an adjustment of the degree of perforation using a sleeve or other means, for example. In the present embodiment, tar loaded pyrolysis gases are allowed to escape from the biomass **204** column through the perforations **134** where they are mixed with preheated air from the air inlet **138**. The pressurized gas entering the tar cracking section **130** provides high temperature turbulence and swirling combustion flows, allowing tar cracking to occur.

The high temperature combustion products being produced in the tar cracking section **130** feed through the annulus **146** into the char gasification section **144**. In the present embodiment, the char gasification section **144** provides for additional biomass decomposition by char gasification reactions. In some embodiments, temperatures of up to 1200 degrees Celsius are attained in the char gasification section **144**.

It can thus be appreciated that biomass entering the combustion chamber **200** will undergo a continuous process whereby the gasification process begins as early as the biomass section **124**. As the biomass is consumed, it is allowed to fall with the aid of the stirrer **126** into the tar cracking section where a majority of the pyrolysis of the process may occur. As the partially consumed biomass exits the tar cracking section **130**, it is allowed to fall downward into the gasification chamber **144** where it may land on the grating **148**. In some embodiments, the reaction of remaining biomass in the column **204** continues on the grating **148**. Gases and heat escaping downward through the combustion chamber **104** and out through the conduit **152** provide energy for the char gasification process on the grating **148**. Thus, a substantially complete reduction process will occur such that gases and essentially inorganic material, or ash, are allowed to flow freely through the conduit **152**.

Table 1 shows the characteristics of pine wood pellets that may be used as a feedstock (biomass) for operation of the gasification system of the present disclosure. Table 2 illustrates a summary of a number of gasification tests conducted utilizing a system constructed in accordance with FIG. 1. The table includes the temperatures reached by various locations within the system **100**, as well as the gases produced in percentage by volume thereof. It can be seen that in some of the tests, tar content and particulates were measured. Efficiency and mass balance percentages are also shown. The mass balance percentages may not add up to exactly 100 due to measurement limitations and rounding errors in equipment.

**Table 1. Wood pellet characteristics**

| | |
|---|---|
| **Proximate,** (weight %, dry basis) | |
| Moisture content | 7.5 ± 0.1 |
| Volatile matter | 82.2 ± 0.6 |
| Fixed carbon | 17.6 |
| Ash | 0.2 ± 0.03 |
| Higher heating value, kcal/kg[a] | 5075 |
| **Ultimate** [a] (weight %, dry basis) | |
| Carbon C | 52.13 ± 1.7 |
| Hydrogen H | 6.36 ± 0.3 |
| Oxygen O | ± 41.23 |
| Nitrogen N | 0.07 ± 0.03 |
| Sulphur S | 0.01 |
| **Diameter (mm)** | 6.0 |
| **Length (mm)** | 10-35 |
| **Bulk density (kg/m$^3$)** | 660 |

[a] BIOBIB. 1992. A database for biofuels. Available at: www.vt.tuwien.ac.at/Biobib/biobib.html. Accessed 8 May 2006.

**Table 2. Summary of typical gasification operation**

| | **Test 1** | **Test 2** | **Test 3** | **Test 4** |
|---|---|---|---|---|
| Equivalence ratio | 0.18 | 0.21 | 0.23 | 0.17 |
| Fuel feed rate, kg/h | 17.0 | 14.8 | 13.0 | 18.1 |
| Input air temperature, C | 216 ± 4 | 205 ± 3 | 216 ± 17 | 219 ± 4 |
| Tar cracking zone (TCZ) temperature, (Ave.), C | 854 ± 43 | 896 ± 38 | 866 ± 48 | 800 ± 48 |
| TCZ temp. (Max.), C | 966 | 1001.7 | 1002 | 975 |
| Char gasification (CG) chamber top, Ave., C | 706 ± 38 | 770 ± 22 | 556 ± 208 | 708 ± 50 |
| CG chamber top, (Max), C | 793 | 819 | 786 | 844 |
| CG chamber mid,(Ave.) C | 742 ± 27 | 790 ± 26 | 607 ± 181 | 731 ± 25 |
| CG chamber mid,(Max.) C | 789 | 827.7 | 768 | 769 |
| Gas temperature after cyclone separator, C | 352 ± 4 | 383 | 350 ± 7 | 356 ± 26 |
| Flame temp. (Ave.), C | 770 ± 25 | 780 ± 31 | 777 ± 30 | 777 ± 24 |
| Flame temp. (Max.), C | 813 | 843.4 | 829 | 829 |
| Pressure drop across gasifier, Inch of water | 11.0 ± 0.6 | 12.0 ± 0.4 | 10.4 ± 0.4 | 10.4 ± 0.3 |
| *Gas composition, % vol.* | | | | |
| CO | 22.7 ± 0.9 | 21 ± 0.9 | 21.2 ± 2.1 | 21.6 ± 1.3 |
| $H_2$ | 10.9 ± 1.6 | 11.9 ± 2.3 | 11.6 ± 1.7 | 12.4 ± 2.2 |
| $CH_4$ | 3.4 ± 0.7 | 3 ± 0.7 | 3.1 ± 0.8 | 3.6 ± 1.1 |
| $CO_2$ | 13.4 ± 0.9 | 13.3 ± 1.1 | 13.4 ± 0.6 | 13.1 ± 1.0 |
| $N_2$ | 48.8 ± 1.7 | 50.3 ± 1.8 | 50 ± 2.1 | 48.3 ± 3.5 |
| $C_2H_2$ | ND* | 0.1 ± 0.2 | ND* | 0.2 ± 0.4 |
| $C_2H_4$ | 0.5 ± 0.1 | 0.4 ± 0.2 | 0.5 ± 0.1 | 0.7 ± 0.3 |
| $C_2H_6$ | 0.2 ± 0.3 | 0.1 ± 0.1 | 0.1 ± 0.3 | 0.1 ± 0.1 |
| LHV gas (kcal/$Nm^3$) | 1369 | 1277 | 1293 | 1423 |
| Dry gas yield ($Nm^3$ /kg) | 1.69 | 1.88 | 2.16 | 1.60 |
| Tar content, g/$Nm^3$ | Not measured | 7.5 | 5 | 12 |
| Particulates, g/$Nm^3$ | Not measured | 0.45 | 0.4 | 0.4 |
| Hot gas efficiency, % | 63.2 | 71.6 | 80.7 | 60.5 |
| Cold gas efficiency, % | 56.3 | 63 | 71.9 | 54 |
| Mass balance, % | 98 | 101 | 105 | 94 |

* Not detected.

Referring now to FIG. 3, an illustration of an exemplary temperature profile of a downdraft gasifier constructed according to aspects of the present disclosure is shown. The measurements of FIG. 3 were taken with a gasifier built according to the present disclosure. Referring also to FIG. 4, the pressure over time of various output gases from the gasifier is shown. With reference to FIGS. 3 and 4, it can be seen that within 60 minutes from system start time, the gasifier system operation was stabilized. FIG. 4 reveals that throughout the test period of three hours, concentration levels of all gases were stable. The present embodiment produces gases with a heating value in the range of 1277 to 1423 kilocalories per cubic meter. Volumetric CO, $H_2$, and $CO_2$ concentrations are in the range of 21-23%, 11-13%, and 13-13.5% percent, respectively. Tar cracking zone temperatures were maintained close to 1000 degrees Celsius. Hot gas efficiency ranged from 63 to 81 percent. Average producer gas flame temperatures were approximately 780 degrees Celsius. Tar and particulate contents in the raw producer gas were in the range of 5 to 12 grams per cubic meter and 0.4 to 0.45 grams per meter cubed, respectively. It can be seen that the results corresponding to the performance of a gasifier constructed according to the present disclosure are comparable to the performance of a conventional throat type downdraft gasifier. This relationship is illustrated for reference in Table 3.

**Table 3. Gasifier performance comparison with other published data on conventional downdraft gasification systems**

| **Feedstock** | **Air-to-fuel ratio, $Nm^3/kg$** | **Tar cracking Temp, $^0$C** | **% Volume CO** | **$H_2$** | **Tar, $g/Nm^3$** |
|---|---|---|---|---|---|
| Hazelnut shells | 1.46 | 1050 | 21 | 13.1 | 3.0 |
| Sewage sludge | 2.3 | 1077 | 10.6 | 10.9 | 6.26 |
| Wood chips | Equivalence ratio of 0.38 | 1000 | 24 | 14 | No data |
| Pine wood pellets (this study) | Equivalence ratio of 0.23 | 1000 | 21 | 12 | 5.0 |

Referring now to FIG. 5, a flow diagram illustrating one method of a gasification process according to the present disclosure is shown. FIG. 5 illustrates a simplified version of one gasification method that may be accomplished by the systems of the present disclosure. At step **502**, biomass is input to the system. At step **504**, the biomass will be stirred and heated. Stirring could be done in a biomass chamber, for example. Heating could be accomplished by a propane flame and/or heated air, or by other means. Pyrolysis begins at step **506**. However, it is understood that stirring and heating may continue to even as pyrolysis occurs.

At step **508** tar cracking occurs. As before, it is understood that pyrolysis may still be occurring when tar cracking has begun. Stirring and heating of the biomass as shown at step **504** may also still be occurring. With reference back now to FIG. 1, it can be seen in the combustion chamber **104** of the system **100** that stirring and heating at **504**, pyrolysis at step **506**, and tar cracking at step **508** may be simultaneously and/or continuously occurring.

Char gasification begins at step **510**. Although char gasification is illustrated as the last of the actual gasification steps, referring again to FIG. 1, it will be clear that the char gasification at step **510** can occur simultaneously with stirring and heating at step **504**, pyrolysis at step **506**, and/or tar cracking at step **508**.

Following the reduction of substantially all of the biomass through pyrolysis, tar cracking, and/or char gasification, the raw gases will be separated from the ash contained therein at step **512**. Following removal of the ash at step **512**, the gas may be output at step **514**. As previously described, the output gas may have a number of uses, such as immediate consumption, storage, and/or further refining.

* * * *

Thus, the present invention is well adapted to carry out the objectives and attain the ends and advantages mentioned above as well as those inherent therein. While presently preferred embodiments have been described for purposes of this disclosure, numerous changes and modifications will be apparent to those of ordinary skill in the art. Such changes and modifications are encompassed within the spirit of this invention as defined by the claims.

## CLAIMS

What is claimed is:

1. A downdraft gasifier comprising:

a biomass feeding unit;

a combustion chamber; and

a separator unit;

wherein the biomass feeding unit accepts raw biomass materials and selectively feeds the materials into the combustion chamber, the combustion chamber providing means to induce pyrolysis, tar cracking, and char gasification of the raw biomass materials to produce gases and ash, the separator unit accepting the gases and ash from the combustion chamber and separating the gases from the ash.

2. The device of claim 1, wherein the means to induce pyrolysis, tar cracking, and char gasification comprises a biomass chamber, a tar cracking chamber, and a char gasification chamber.

3. The device of claim 2, wherein the tar cracking chamber further comprises substantially cylindrical inner and outer walls.

4. The device of claim 3, wherein the inner wall defines a plurality of perforations on at least a portion thereof.

5. The device of claim 4, further comprising means for selectively closing the perforations.

6. The device of claim 2, wherein the means to induce pyrolysis, tar cracking, and char gasification further comprises a stirrer operable to stir biomass in the combustion chamber through at least the biomass chamber and a portion of the tar cracking section.

7. The device of claim 2, wherein the means to induce pyrolysis, tar cracking, and char gasification further comprises a heat source.

8. The device of claim 1, wherein the separator unit comprises a cyclonic separator.

9. A cyclonic combustion chamber comprising:

a biomass chamber with a stirrer that accepts biomass material and stirs it;

a tar cracking chamber feeding from the biomass chamber, the tar cracking chamber gasifying the biomass material by pyrolysis and tar cracking of the biomass material through application of heat; and

a char gasification chamber having a grating for trapping remaining biomass material from the tar cracking chamber and holding the same during a period of char gasification.

10. The cyclonic combustion chamber of claim 9, wherein the biomass chamber is above the tar cracking chamber, which is above the char gasification chamber, such that the biomass material is gravity fed through the combustion chamber.

11. The cyclonic combustion chamber of claim 9 further comprising an outlet conduit for removing the gasified biomass material and ash from the combustion chamber.

12. The cyclonic combustion chamber of claim 9, wherein the tar cracking chamber further comprises inner and outer walls, the inner wall defining a plurality of perforations therein.

13. The cyclonic combustion chamber of claim 12, wherein the plurality of perforations are selectively closable.

14. A method of producing gases from biomass, the method compring:

heating biomass materials to induce pyrolysis;

feeding the biomass materials into a tar cracking chamber to induce tar cracking; and

feeding the biomass materials into a char gasification chamber for char gasification.

15. The method of claim 14, wherein heating further comprises heating with fuel combustion.

16. The method of claim 14, wherein heating further comprises heating with heated air.

17. The method of claim 14, further comprising:

collecting gases and ash resultant from the pyrolysis, tar cracking, and char gasification through a single conduit; and

separating the collected gases and ash.

18. The method of claim 14, further comprising stirring the biomass through at least a portion of the pyrolysis and the tar cracking.

19. The method of claim 14, wherein feeding the biomass materials into a tar cracking chamber and feeding the biomass materials into a char gasification chamber are accomplished via a gravity feed.

20. The method of claim 14, wherein feeding the biomass materials into a tar cracking chamber to induce tar cracking further comprises feeding the biomass materials into a double-walled tar cracking chamber, the inner and outer wall being substantially cylindrical, and the inner wall defining a plurality of perforations sized to allow gasses to flow therethough.

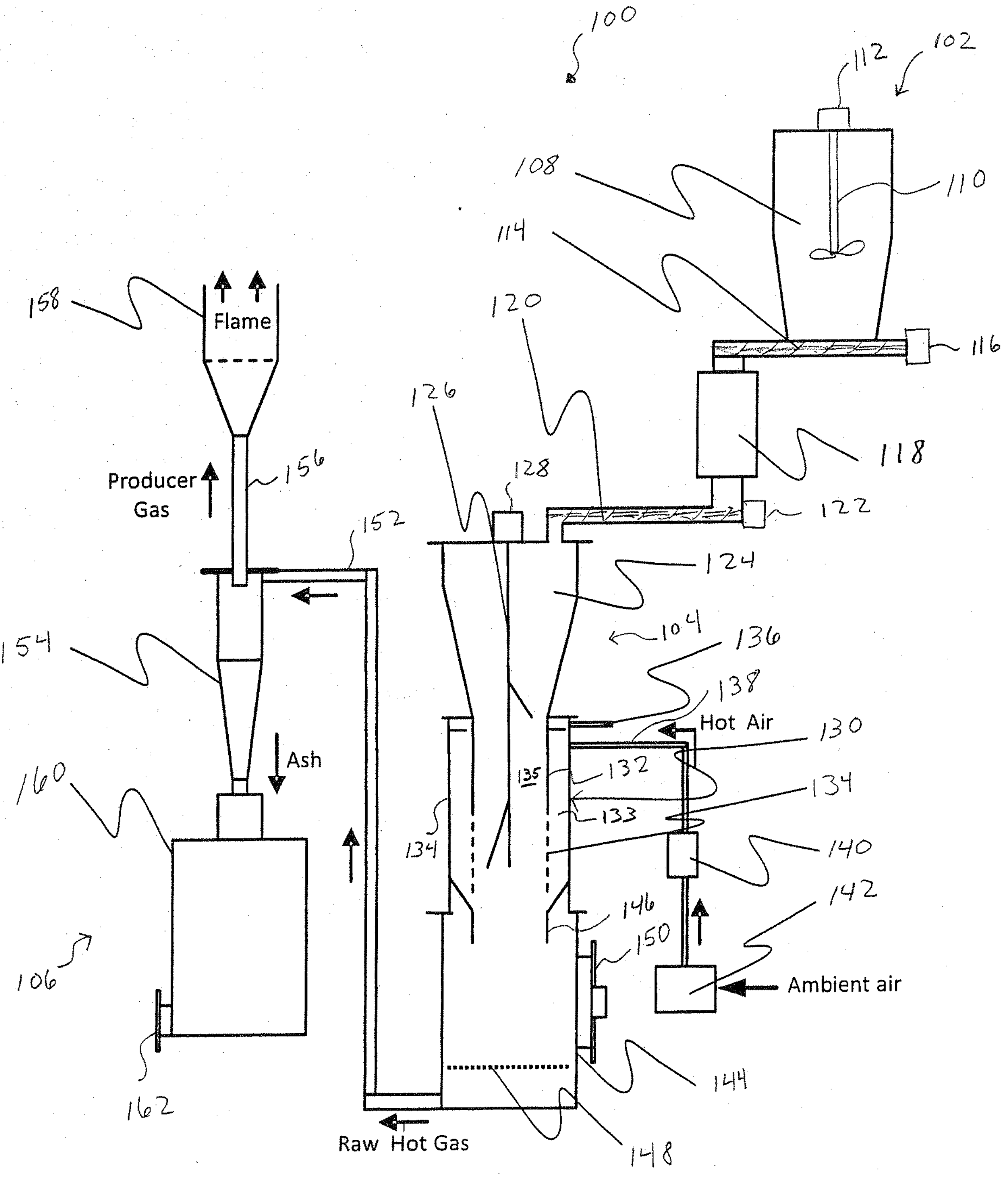
100
102
112
108
110
114
116
118
120
122
126
128
124
104
136
138
Hot Air
130
132
135
133
134
134
140
142
Ambient air
146
150
144
148
Raw Hot Gas
158
Flame
Producer Gas
156
152
154
Ash
160
106
162

FIG 1

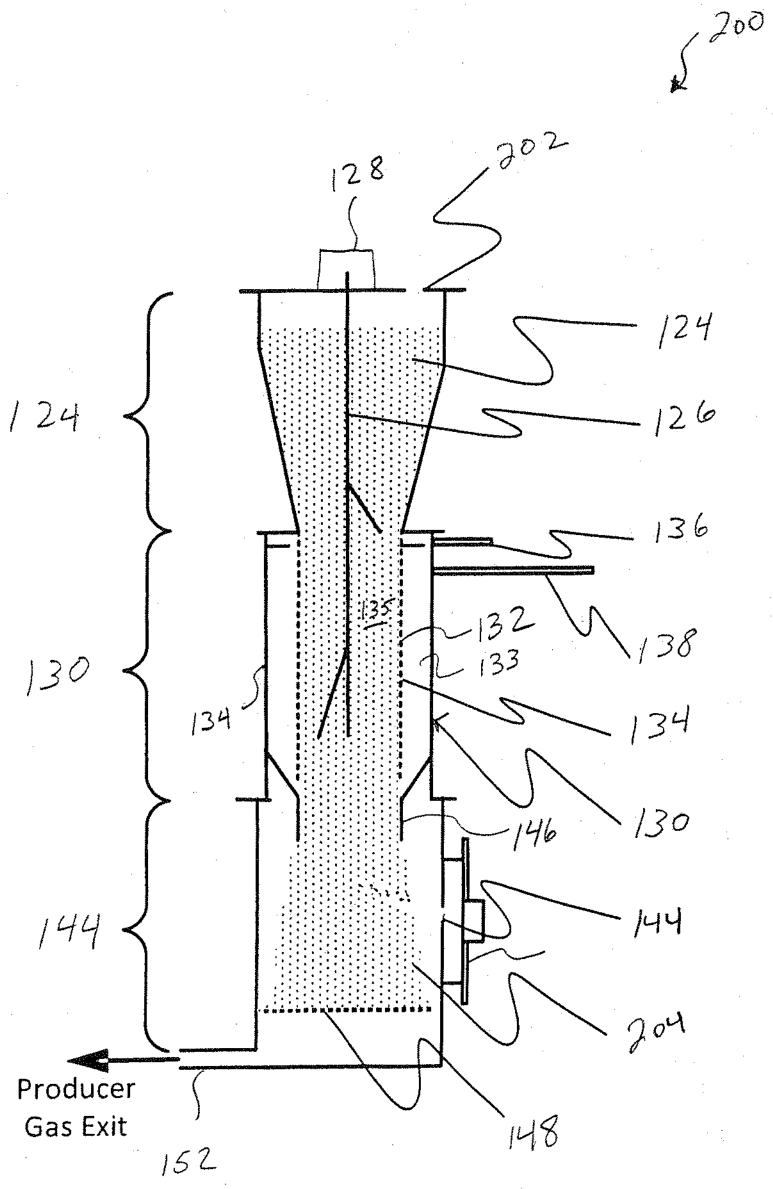
200
128
202
124
124
126
136
138
135
132
133
130
134
134
130
146
144
144
204
148
Producer
Gas Exit
152

FIG 2

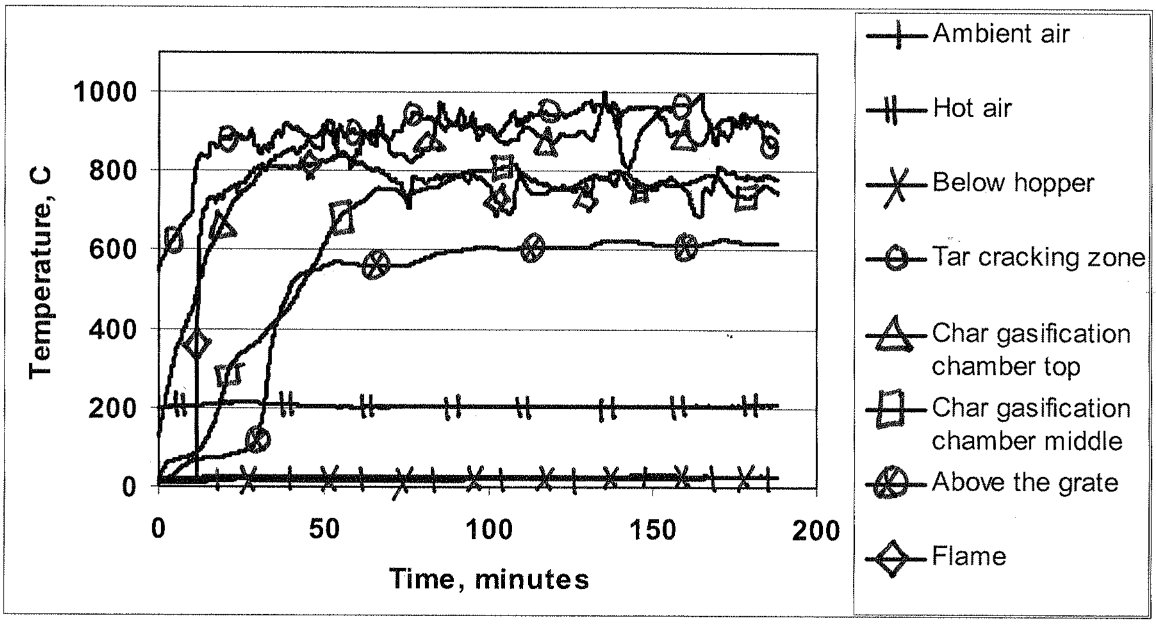
1000
800
600
400
200
0
Temperature, C
0
50
100
150
200
Time, minutes
Ambient air
Hot air
Below hopper
Tar cracking zone
Char gasification chamber top
Char gasification chamber middle
Above the grate
Flame

FIG 3

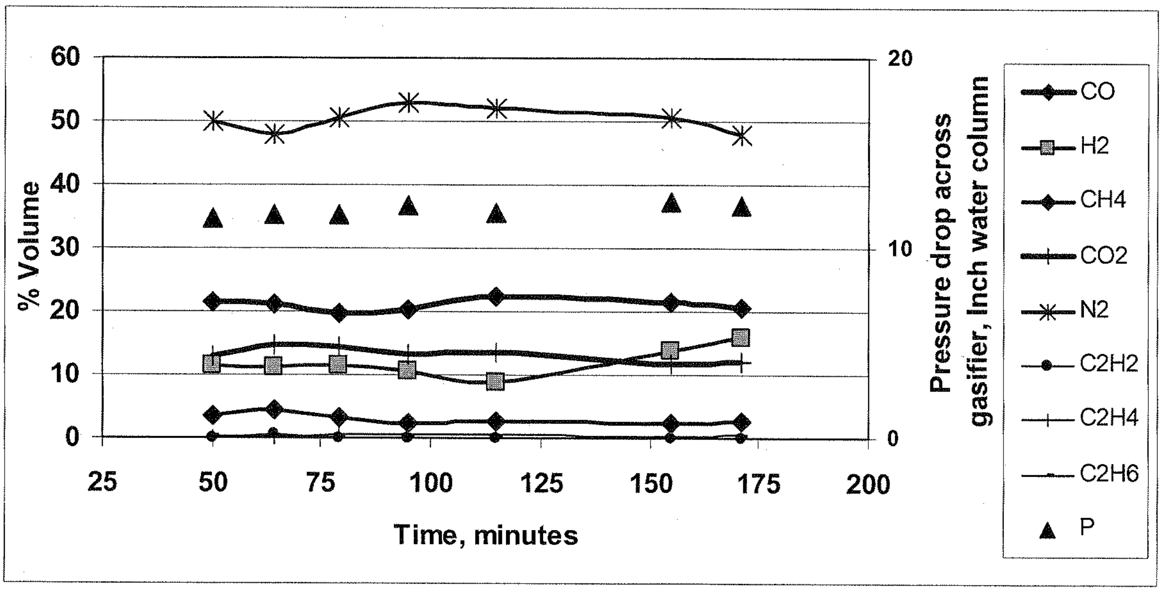
60
50
40
30
20
10
0
% Volume
20
10
0
Pressure drop across gasifier, Inch water column
25
50
75
100
125
150
175
200
Time, minutes
CO
H2
CH4
CO2
N2
C2H2
C2H4
C2H6
P

FIG 4

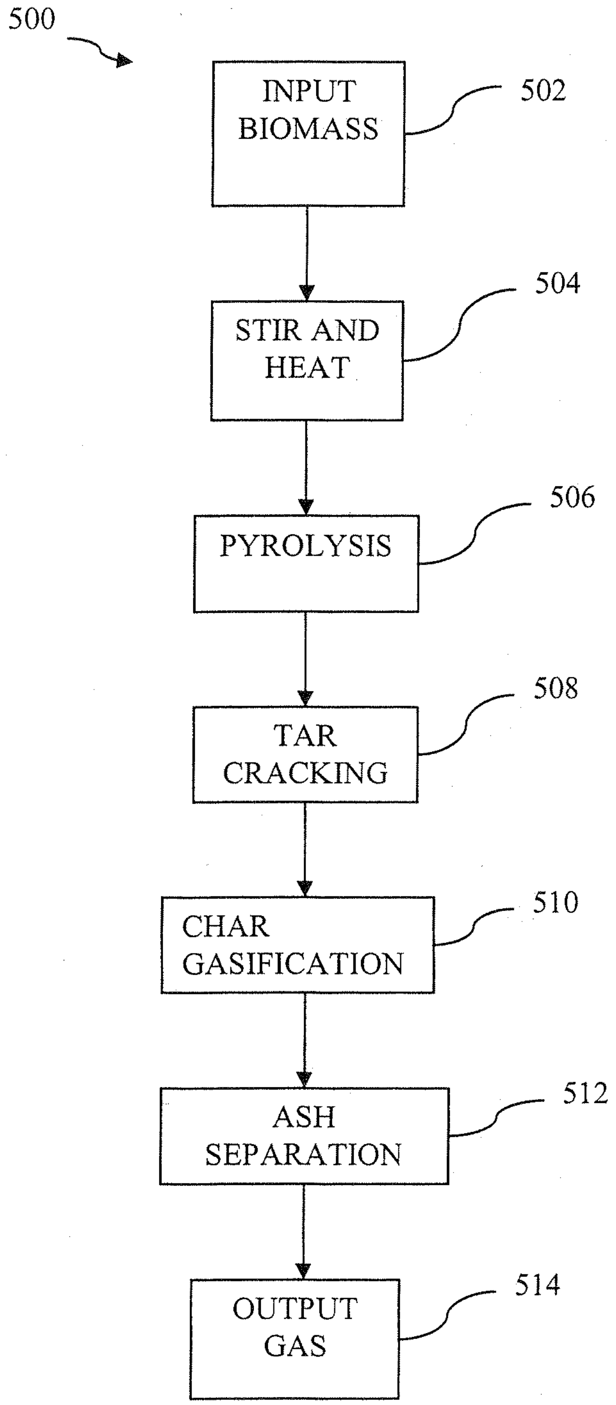
500
INPUT BIOMASS
502
STIR AND HEAT
504
PYROLYSIS
506
TAR CRACKING
508
CHAR GASIFICATION
510
ASH SEPARATION
512
OUTPUT GAS
514

**FIG. 5**