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(54) **HIGH EFFICIENCY CYCLONE GASIFYING COMBUSTION BURNER AND METHOD**

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(57) **ABSTRACT**

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A cyclone gasifying combustion burner and its operation is described. An exemplary burner has an inner cylindrical wall with a contour chamber feeding combustion air into the inner cylindrical wall, with an open end and a solid fuel support end where a combustible material forms a fuel bed. The inner cylindrical wall has a series of inclined air jet holes of substantially predetermined diameter and disposed at substantially predetermined locations therein to create a unidirectional cyclone within a combustion zone defined within the inner cylindrical wall. The air jet holes are disposed at a tangential and vertical angle whereby the combustion air is drawn into the inner cylindrical wall and creates a cyclone flow to mix with the combustion gases released from the flaming pyrolysis fuel bed and causes the combustion gases to flow in a cyclone path within a reaction zone to increase the residency, mixing and turbulence time of the combustion gases and simultaneously precipitate suspended particles against an inner surface of the inner cylindrical wall whereby the particles are caused to gravitate to the fuel bed where they are removed in a controlled manner during the operation of the burner.

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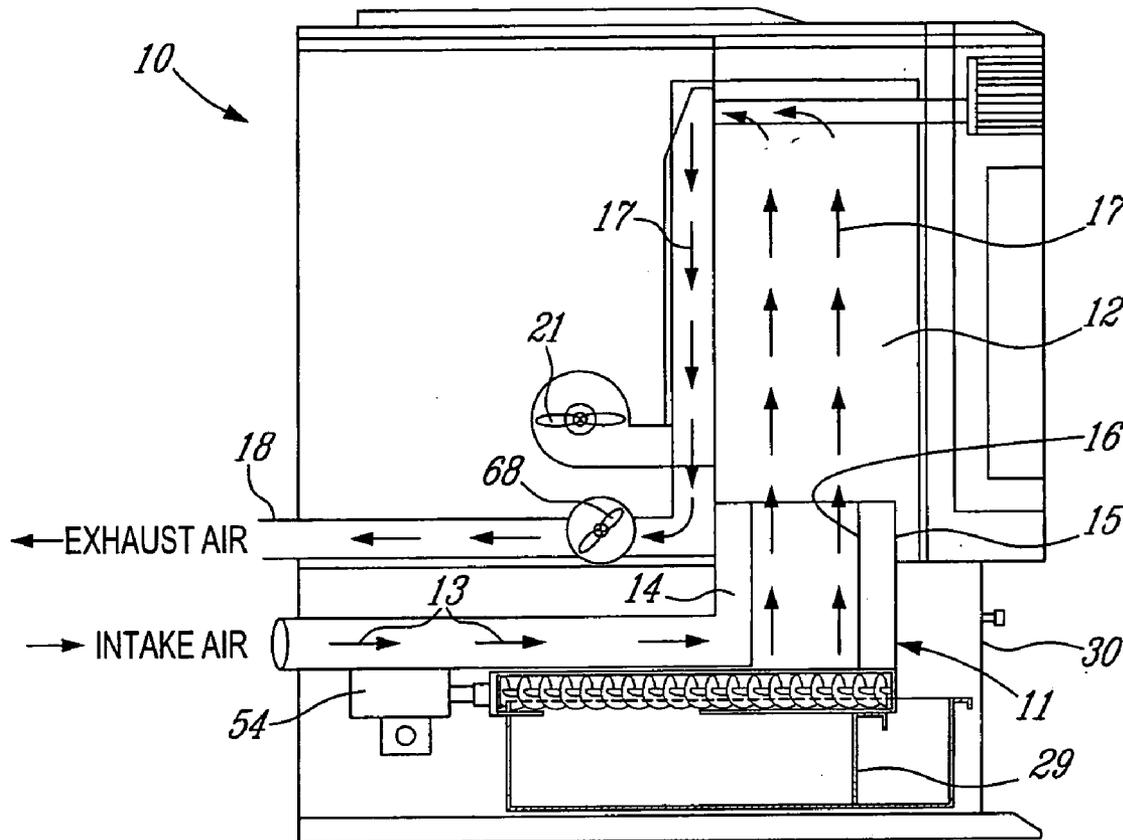
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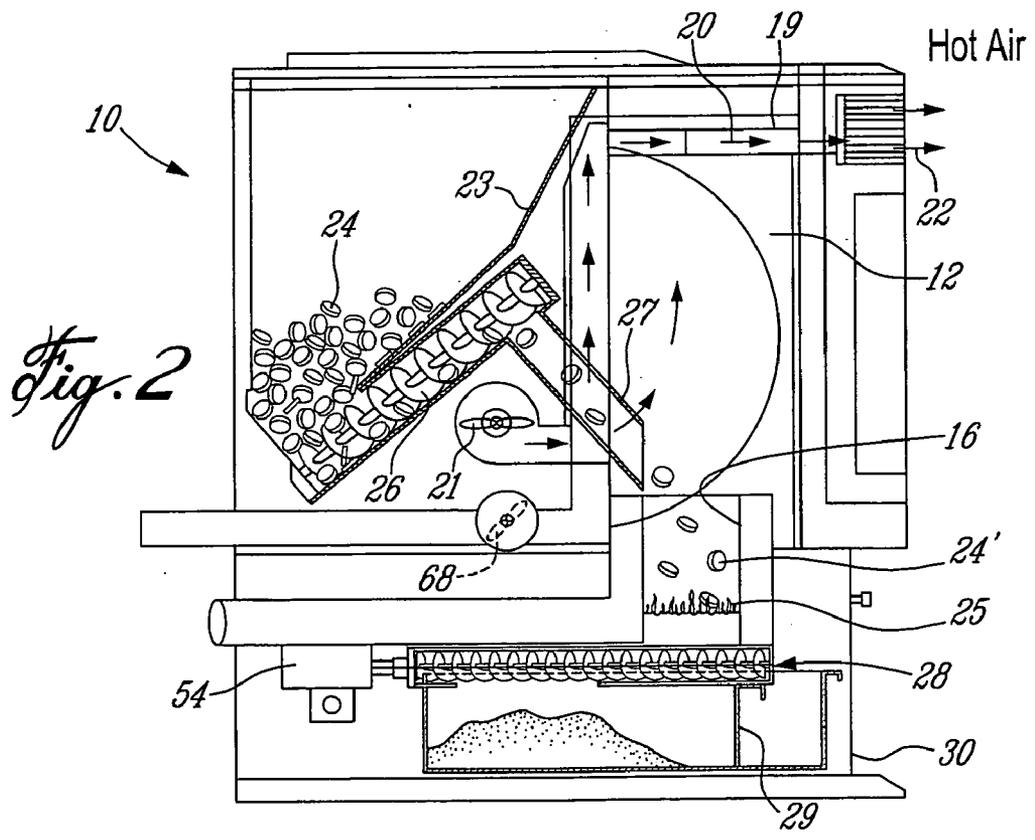
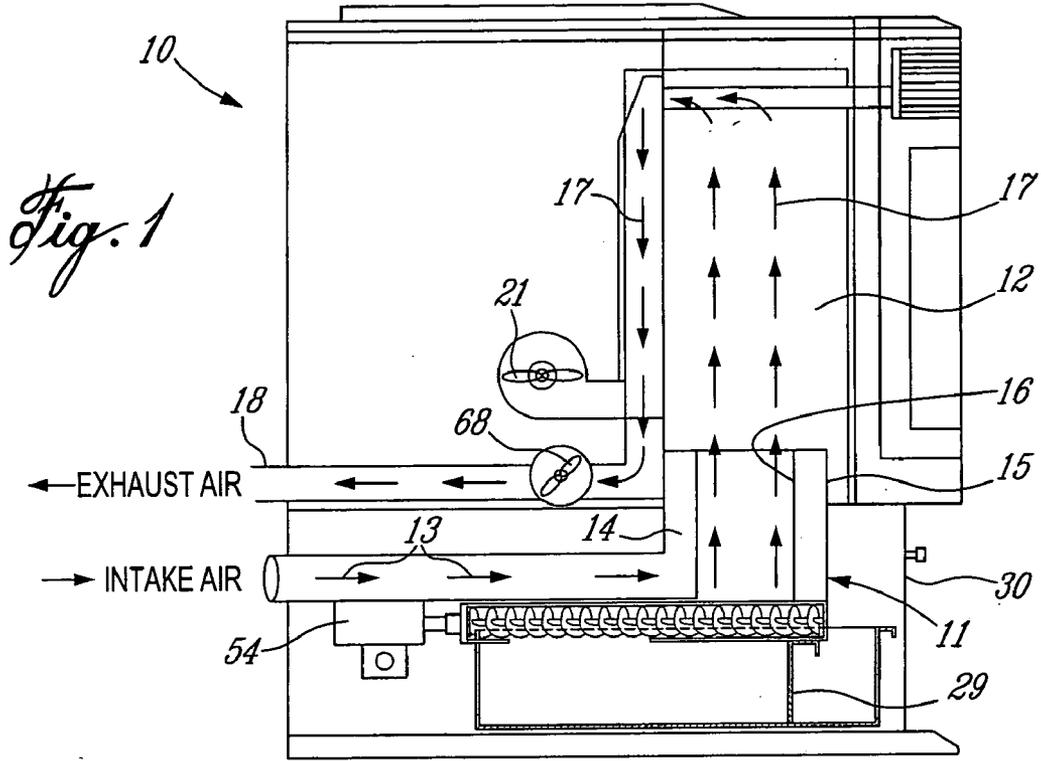
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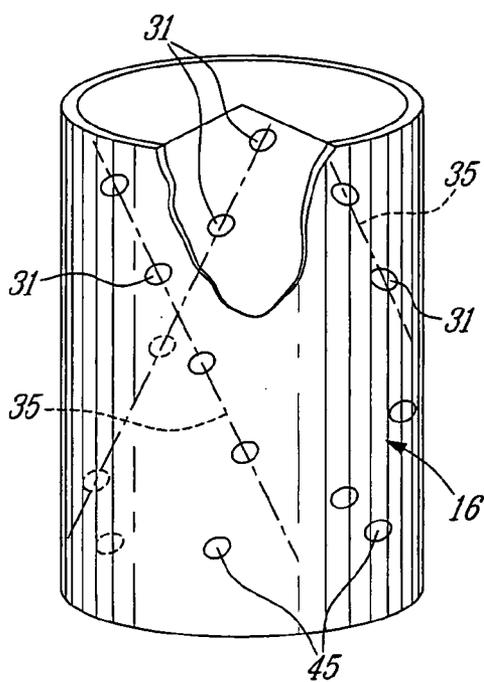
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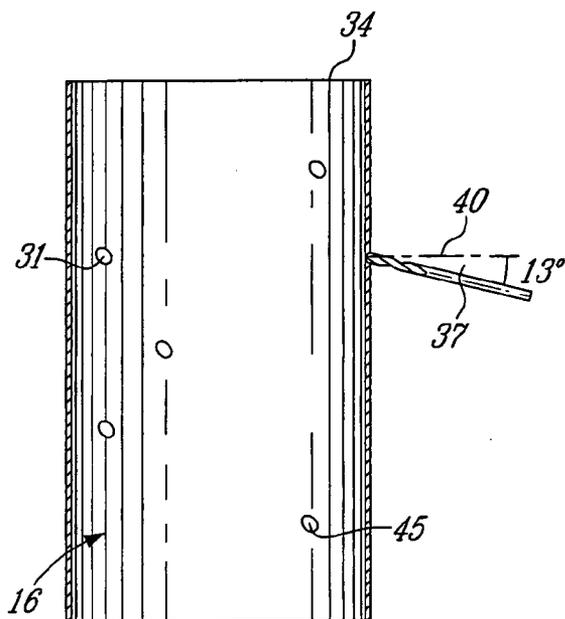
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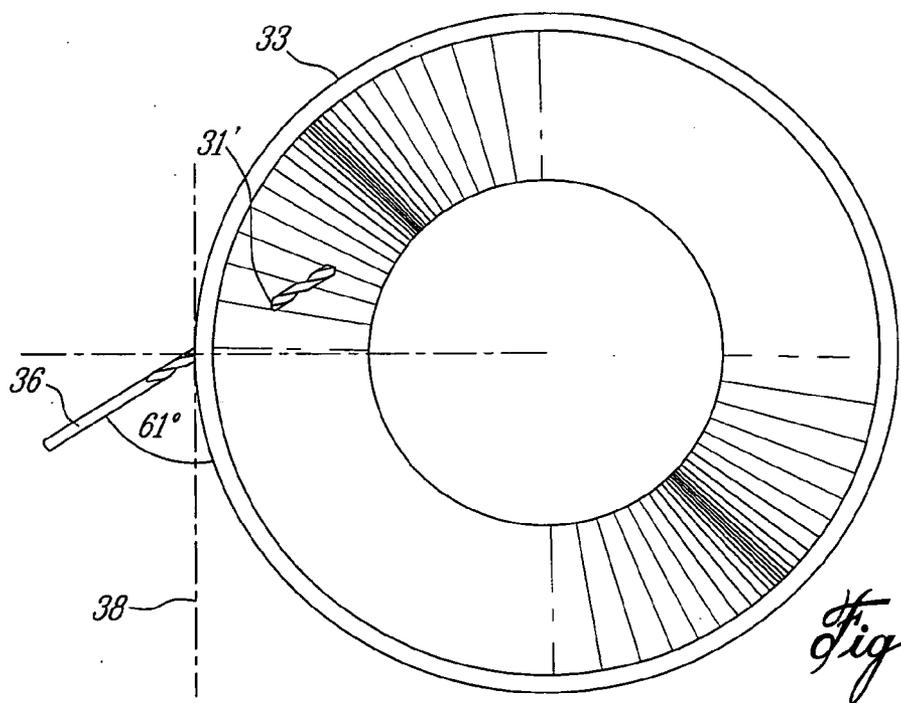




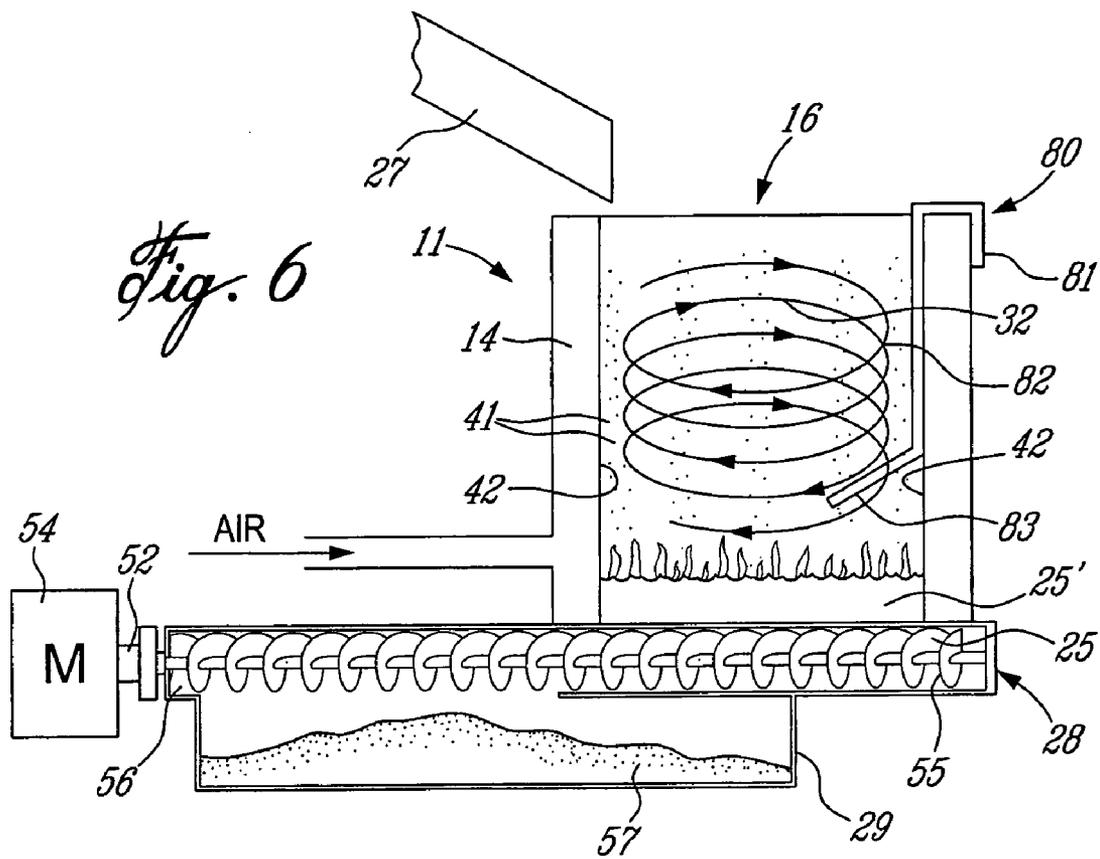
*Fig. 3*

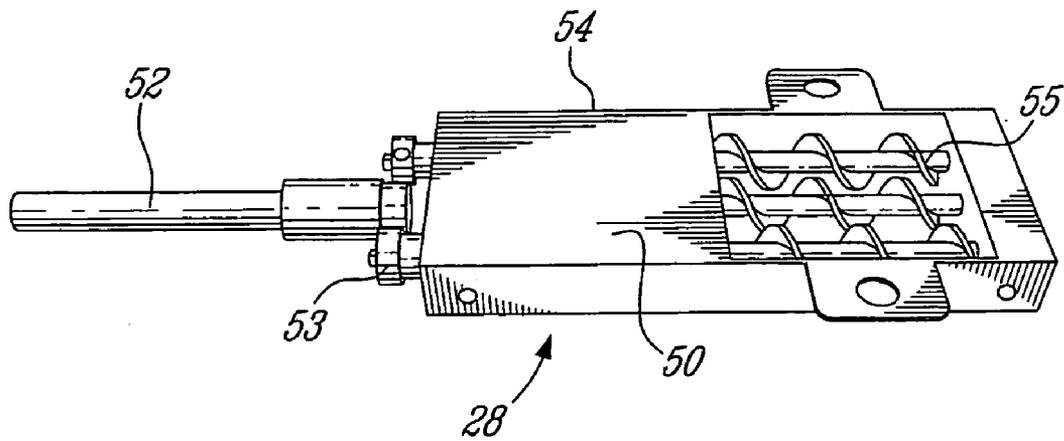


*Fig. 4*

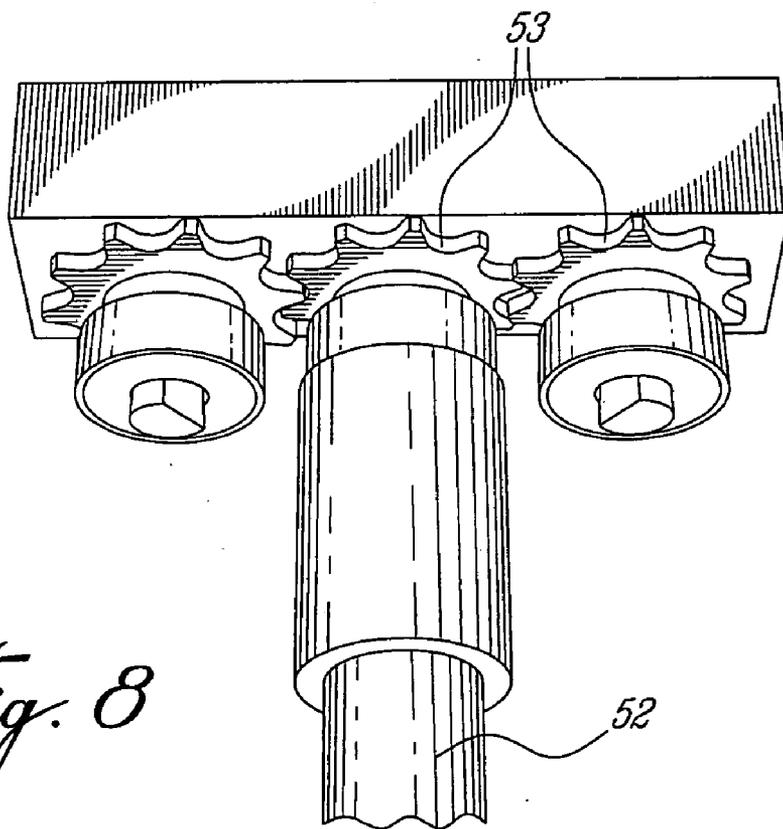


*Fig. 5*

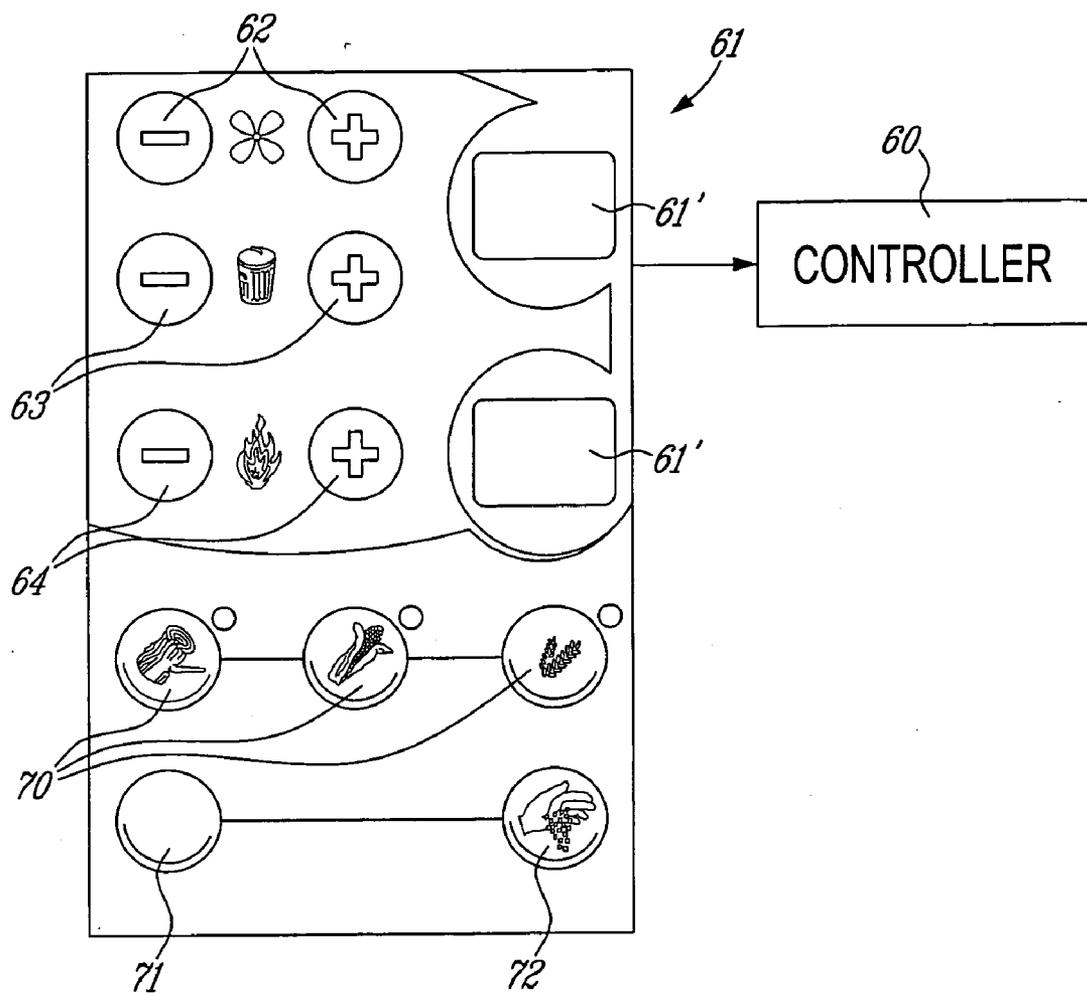




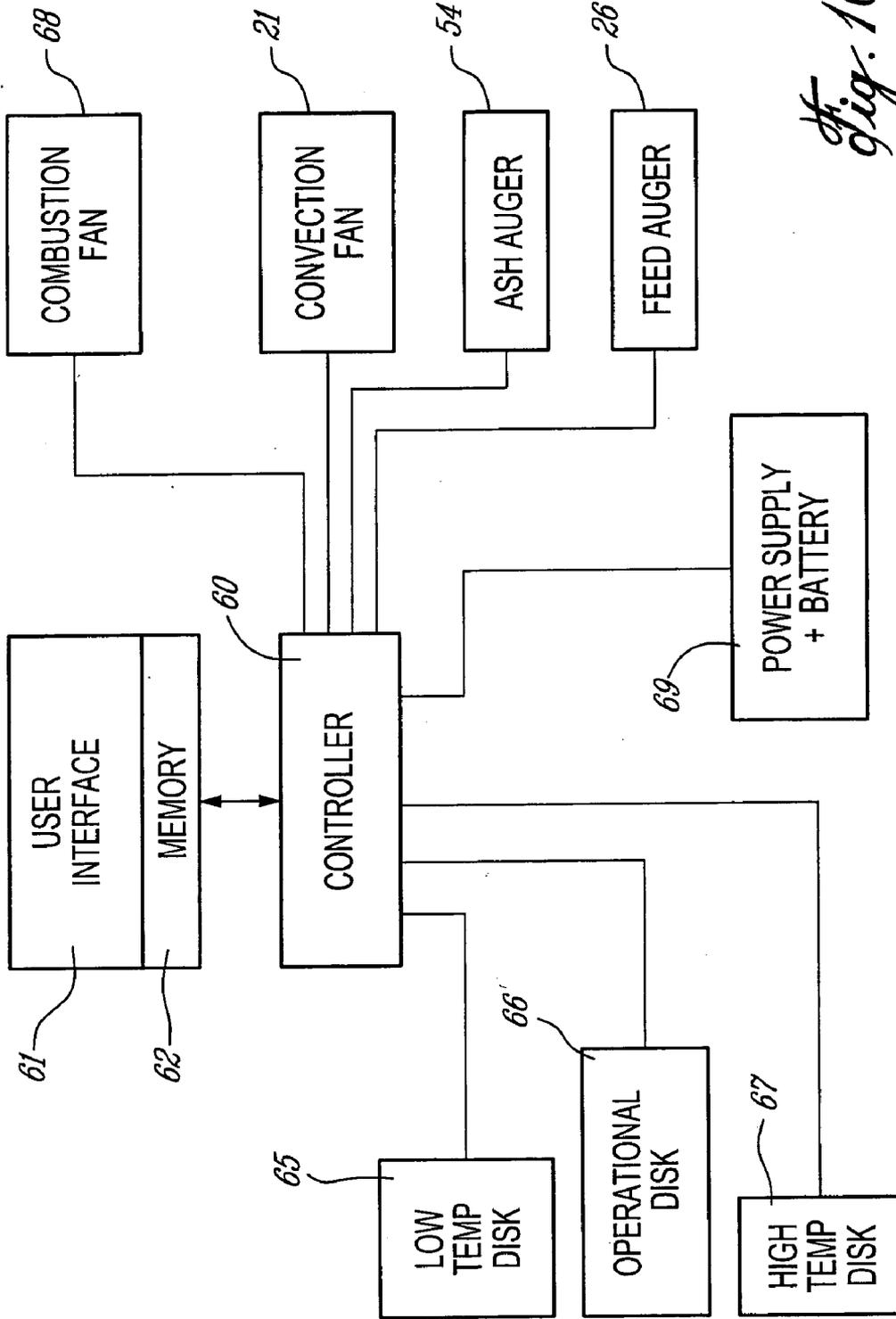
*Fig. 7*



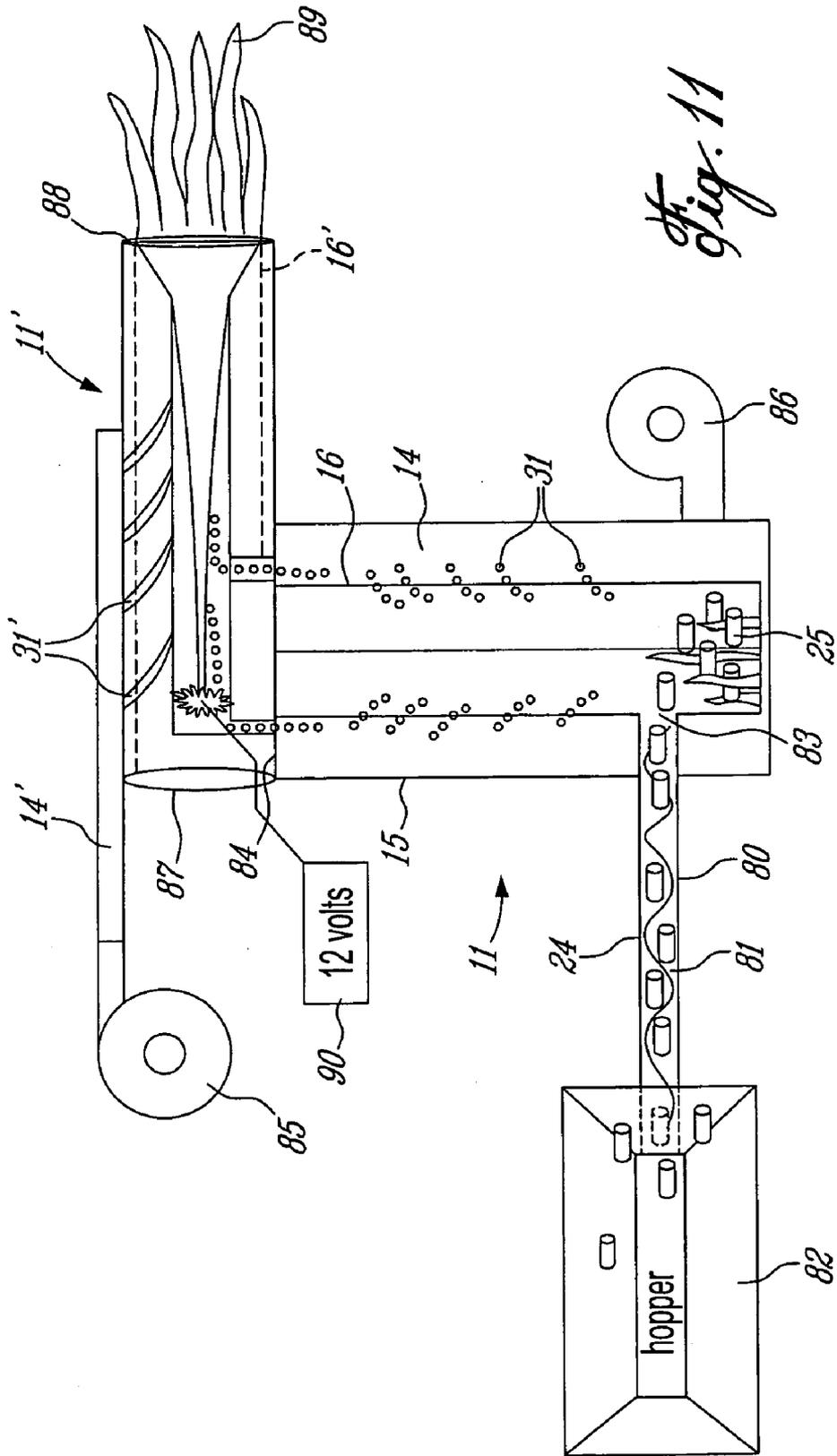
*Fig. 8*



*Fig. 9*



*Fig. 10*



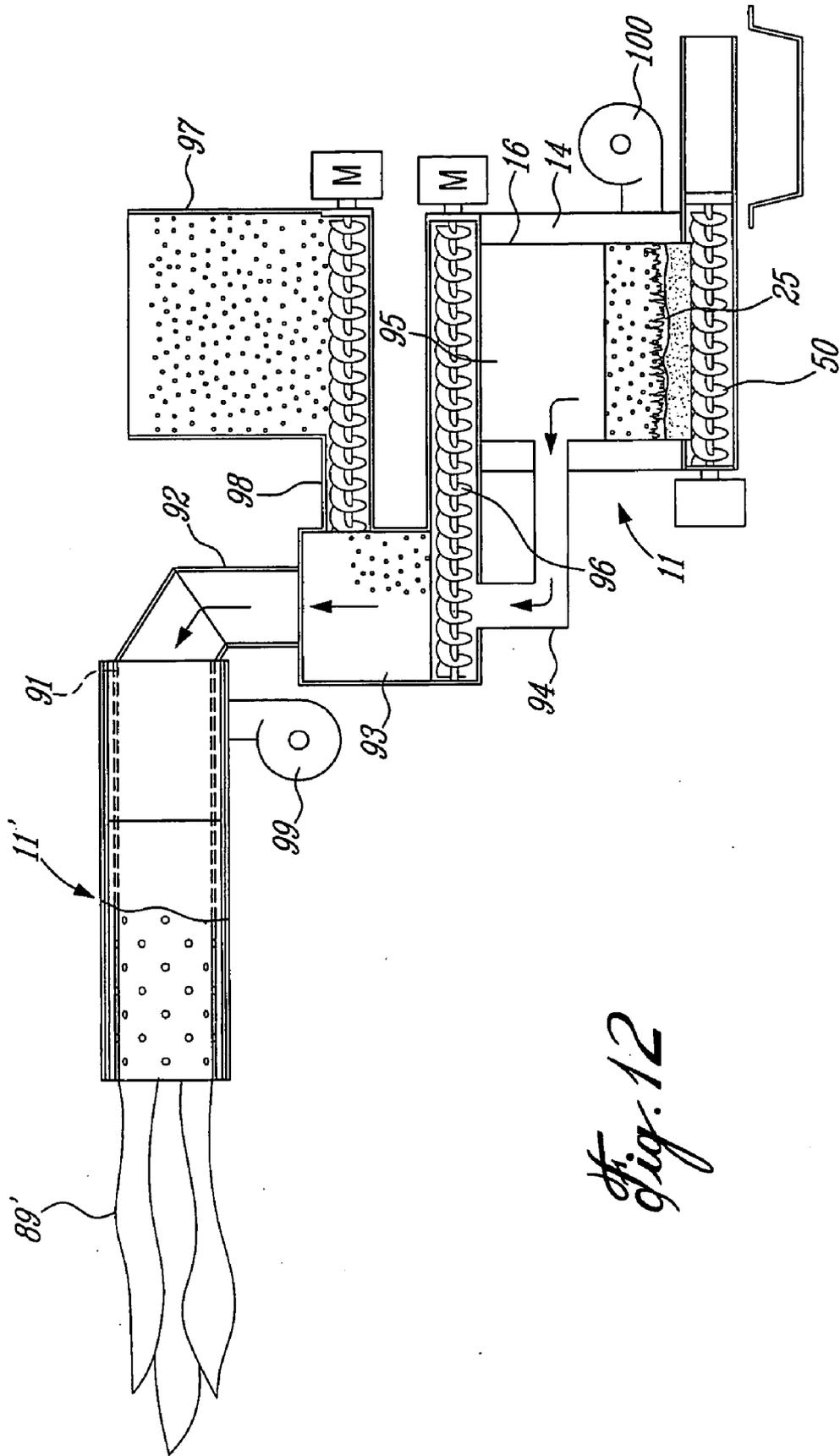
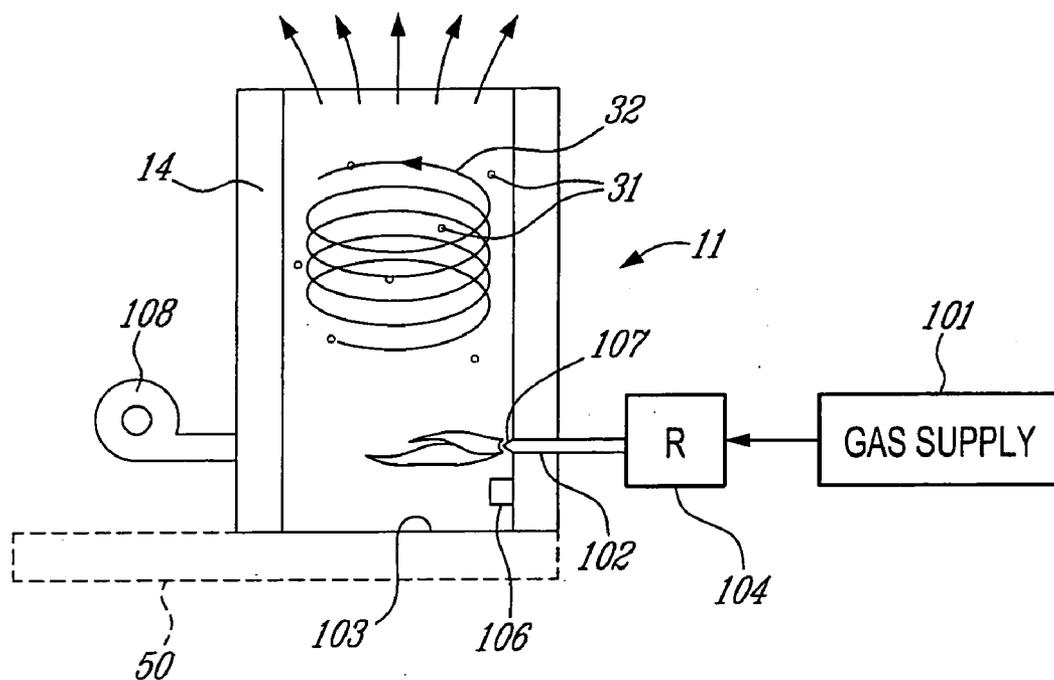
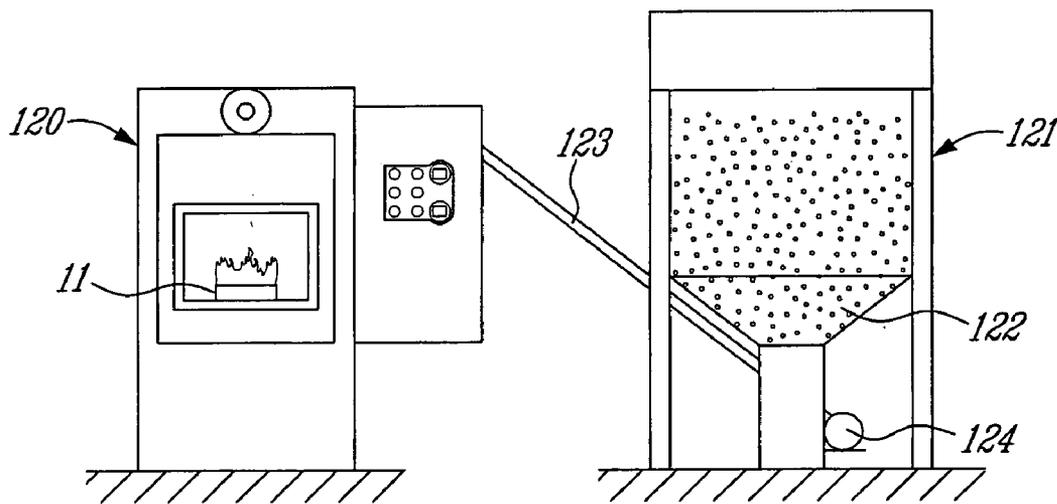


Fig. 12



*Fig. 13*



*Fig. 14*

## HIGH EFFICIENCY CYCLONE GASIFYING COMBUSTION BURNER AND METHOD

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Canadian Patent Application No. \_\_\_\_\_, filed on Dec. 15, 2005, and entitled "High Efficiency Cyclone Gasifying Combustion Burner to Produce Thermal Energy and Devices and Method of Operation", and hereby incorporated by reference.

### TECHNICAL FIELD

[0002] The present invention relates in general to fuel burners, and in particular to a high-efficiency cyclone gasifying combustion burner and methods of operation.

### BACKGROUND ART

[0003] In U.S. Pat. No. 6,336,449, a solid fuel burner is disclosed of cylindrical shape with holes disposed in an inner cylindrical wall to create a swirling motion to burn the combustion gases. Further experimental work and testing of this concept has led to important improvements beneficial to human health.

[0004] There has been a considerable increase in the use of wood-burning devices to heat residential buildings. This increase has been precipitated by the high cost of oil and gas. However, these wood-burning devices pollute the atmosphere and are harmful to human health.

[0005] According to Environment Canada, a woodstove that is not certified emits as many fine particles into the air in nine hours as does a certified woodstove in 60 hours or a mid-size automobile traveling 18,000 km in one year. Heating with wood represents a major source of contaminant discharge into the air: carbon monoxide (CO), volatile organic compounds (VOC), fine particles (PM<sub>2.5</sub>), nitrogen oxides (NO<sub>x</sub>) and polycyclic aromatic hydrocarbons (PAH, among others). Smoke from the combustion of wood is present in both inside and outside the home.

[0006] In residential neighbourhoods where wood heating is common, exposure to contaminants from chimney smoke can have a significant impact on health.

[0007] In the Province of Quebec, Canada, wood-fire home heating is responsible for half of the fine particle emissions associated with human activities. At the local level, wood combustion may contribute far more severely to pollution. For example, a report by the Montreal Urban Community has shown that, in winter, the concentrations of fine particles, VOC's and PAH's were often higher in residential neighbourhoods than in the downtown sector. Under certain weather conditions, the concentration of contaminants in the ambient air can reach high levels in certain neighbourhoods. This type of situation can occur in many places.

[0008] The number of wood-heating systems is increasing in Canada and many other countries in the world. Statistics Canada data indicates that the number of dwellings using wood heating increased by about 60% from 1987 to 2000. During the same period, the number of dwellings increased by less than 20%. This is true also for many cities of the world employing wood heating-systems.

[0009] The particles emitted when heating with wood are very small, less than 2.5 microns, allowing them to penetrate deep into the respiratory tract, affecting breathing. The following Table illustrates the potential health impacts of certain contaminants from high concentration of wood smoke in the air.

Contaminants		Effects
Carbon monoxide	CO	Headaches, nausea, dizziness, aggravation of angina in people with cardiac problems
Volatile organic compounds	VOC	Respiratory, irritation and difficulties, certain VOC are carcinogenic (ex: Benzene)
Acrolein and formaldehyde	—	Irritation of the eyes and respiratory system
Fine particles	PM <sub>2.5</sub>	Irritation of the respiratory system, aggravation of cardiorespiratory diseases, hastened mortalities
Nitrogen oxides	NO <sub>x</sub>	Irritation of the respiratory system, painful inhalation, coughing, pulmonary oedema
Polycyclic aromatic hydrocarbons	PAH	Certain PAH are considered or suspected of being mutagenic or carcinogenic
Dioxins and furans	—	Potentially carcinogenic

[0010] The magnitude of these effects depend upon people's sensitivity. Very young children, the elderly and individuals who suffer from asthma, emphysema or heart problems are among the most sensitive to air pollution.

[0011] In addition to emitting contaminants outdoors, wood combustion units may alter the quality of the air inside the home as portions of the combustion gases and fine particles make their way back indoors. These leaks inside the home will vary in importance according to the type of unit used, the quality of its installation and the way in which the homeowner operates the wood-burning unit. A study carried out by the Direction de la santé publique de Montréal-Centre showed that people using a woodstove had higher concentrations of contaminants in their urine than people without woodstoves. The combustion of wood thus represents an additional source of exposure to toxic substances in the home. Unlike most solid fuel burning devices, the burner of this invention can utilize solid fuels like wood and other types of non wood based solid fuels and substantially reduce emissions of toxic components during combustion.

[0012] Each type of mineral that may be present in the solid fuel has a known melting point, and some of these minerals are further transformed by temperature into a gas vapor state, a term known as alkali metal species migration. Some of these minerals occurring substantially as potassium and chlorides, which may have lower melting points than for example silicates, pose many difficulties during and after combustion of the fuel, as they promote the agglomeration (by melting and or cooling into masses) of minerals on adjacent metal surfaces. The deposition of inorganic elements such as alkali metals can have a significant impact on an operating system's overall performance, which further impacts on the efficacy of the operating system over time. Agriculture based fibers usually contain higher levels of chlorides and potassium salts.

[0013] The high cost of natural gas and fuel oil and our dependency thereon and the effects of burning fossil fuels on climate change is another reason why alternate clean sources of energy are required today. According to the United Nations and the scientific community, the combustion of solid Biomass fuel, is considered to be green house gas neutral, that is, absorbing the equivalent CO<sub>2</sub> (carbon dioxide) during growth as is emitted during combustion.

#### SUMMARY OF INVENTION

[0014] In accordance with various aspects of the present invention, a cyclone gasifying combustion burner is configured for use in or coupled to a solid fuel biomass device that substantially eliminates various disadvantages of woodstoves or other solid fuel combustion devices. For example, an exemplary burner and method of operation can substantially reduce the emission levels of volatile organic compounds (VOC), particulates and fly ash as well as the level of nitrogen oxide (NO<sub>x</sub>) and/or all other carbon and volatile gases released during combustion of a solid fuel.

[0015] In accordance with an exemplary embodiment, a cyclone gasifying combustion burner can be incorporated into or coupled to a device having a thermal energy source and that can be automatically controlled in a modulated manner to achieve optimum efficiency. Such a cyclone gasifying combustion burner can comprise a fuel bed support system, such as a pyrolytic fuel bed, that automatically removes ashes from the fuel bed and thereby substantially reduces emission of volatile organic compounds, particulates, fly-ash, nitrogen oxides and other pollutants into the atmosphere. In accordance with another aspect, a cyclone gasifying combustion burner can also be configured such that the fuel bed temperature is starved of combustion air whereby to reduce the temperature of the fuel bed to prevent the fusion of inorganic elements within the solid fuel. An exemplary cyclone gasifying combustion burner may also be coupled to heating devices for residential, commercial and industrial applications, whereby to replace fossil fuel dependent heating devices. Such heating devices incorporating the cyclone gasifying combustion burner can also be configured to achieve significant reduction of greenhouse causing gases.

[0016] In accordance with an exemplary embodiment, a cyclone gasifying combustion burner comprises a combustion housing defined by an inner cylindrical wall surrounded by a manifold chamber having combustion air inlet devices and mechanisms. The inner cylindrical wall has air jet holes therein of substantially predetermined diameter and disposed at a substantially predetermined angle to create an air cyclone flow in a reaction zone in the inner cylindrical wall and spaced above a lower air-starved gasifying fuel bed thereof. The cyclone flow in the reaction zone can increase the residency time, turbulence, and mixing of oxygen and volatile gases to substantially complete combustion of the gases drawn into the reaction zone and causes suspended particles to gravitate into the fuel bed and thereby substantially reduce the emission of pollutants into the atmosphere.

[0017] In accordance with an exemplary embodiment, a device having a combustion chamber and requiring a thermal energy source can be configured in combination with the cyclone combustion burner. A heat exchanger can be provided in the combustion chamber. An air displacement

system or device can create a negative pressure in the combustion chamber to displace hot air against the heat exchanger and to draw air through the air jet holes in the inner cylindrical wall of the combustion chamber. Mechanisms are provided to control the air displacement systems. In accordance with an exemplary embodiment, the combustion burner comprises a low pressure burner having an air/fuel ratio of about 6:1 to 10:1.

[0018] In accordance with an exemplary embodiment, there is provided a controller for automatically controlling the operation of the heating device. A user interface pad, having a memory and switch means, is also provided to set parameters into the controller relating to a desired mode of operation. The pad is also equipped with visual display device.

[0019] In accordance with another aspect of the present invention, there is provided a method of substantially reducing the emission levels of volatile organic compounds (VOC), particulates entrained fly ash, and the level of nitrogen oxides (NOX) during combustion of a solid fuel. In accordance with an exemplary embodiment, an exemplary method comprises the steps of feeding the solid or gas fuel in particle-form into an open end of a cyclone gasifying combustion burner and onto a flaming pyrolysis fuel bed thereof. The fuel bed is disposed below a reaction zone of the burner. The burner has a burner chamber defined by an inner cylindrical wall having a predetermined number of inclined air jet holes of predetermined diameter and height disposed at substantially predetermined locations to create a cyclone air flow within the reaction zone when combustion air is drawn therethrough. Air is drawn into the burner chamber through the inclined air jet holes whereby to draw combustion gases from the fuel bed into the reaction zone to mix with the cyclone air flow thereby substantially increasing the residency time of the combustion gases in a turbulent, mixing of oxygen and volatile gases for substantially complete combustion of gases and tars in the reaction zone and to simultaneously precipitate suspended particles against an inner surface of the inner cylindrical wall to cause at least some of the particles to agglomerate with other particles to increase their molecular weight and gravitate to the fuel bed.

[0020] In accordance with an exemplary embodiment, the vertical combustion housing has an open top end. A mechanism is provided to feed a solid biomass fuel in a particle, granular, pellet or whole or partial grain form to the fuel bed. A further combustion housing having an inner cylindrical wall surrounded by a manifold chamber is also provided. The inner cylindrical wall of the further combustion housing has air jet holes therein to create a reaction zone for the combustion of gases. The further combustion housing has a closed end wall and an opposed open end wall and is secured adjacent to the closed end wall to an open top end of the combustion housing and extends substantially transversely thereto. The inner cylindrical wall of both the vertical combustion housing and the further combustion housing communicate with one another to form a continuous internal combustion chamber.

[0021] In accordance with an exemplary embodiment, the further combustion housing has an open rear end and an open front end. The open rear end is connected to the open top end of the vertical combustion housing by conduit means

for the supply of hot combustible gases released from the open top end for mixing with an air cyclone of the further combustion housing.

[0022] In accordance with an exemplary embodiment, there is provided a cyclone gasifying combustion burner having a combustion housing defined by an inner cylindrical wall surrounded by a manifold chamber having a combustion air inlet mechanism or system. The inner cylindrical wall has air jet holes therein of predetermined diameter and disposed at a predetermined angle to create an air cyclone flow in a reaction zone in the inner cylindrical wall spaced above a lower combustion gas supply. The cyclone flow in the reaction zone increases the residency time, turbulence, mixing of oxygen with volatile gases for substantially complete combustion of gases drawn in the reaction zone thereby substantially reducing the emission of pollutants into the atmosphere.

[0023] In accordance with an exemplary embodiment, a method of substantially reducing the emission levels of any one of volatile organic compounds (VOC), particulates, entrained fly ash, and/or the level of oxygen oxides (NO<sub>x</sub>) during combustion of a gas can comprise supplying a combustion gas from below a reaction zone of a cyclone gasifying combustion burner. For example, the burner can comprise a burner chamber defined by an inner cylindrical wall having a substantially predetermined number of inclined air jet holes of substantially predetermined diameter disposed at substantially predetermined locations to create a cyclone air flow within the reaction zone when combustion air is drawn therethrough. The method further comprises drawing air into the burner chamber through the inclined air jet holes whereby to draw the combustion gases into the reaction zone to mix with the cyclone air flow thereby increasing the residency time of the combustion gases, turbulence, and mixing of oxygen with volatile gases for substantially complete combustion of gases in the reaction zone to substantially reduce the emission of pollutants into the atmosphere.

BRIEF DESCRIPTION OF DRAWINGS

[0024] The exemplary embodiments of the present invention will be described in connection with the appended drawing figures in which like numerals denote like elements, and wherein:

[0025] FIG. 1 is a simplified side view, partly sectioned, of an exemplary pellet stove heating device and showing the airflow path through the cyclone combustion burner and through a heat exchanger chamber of the device and out through a flue conduit in accordance with an exemplary embodiment of the present invention;

[0026] FIG. 2 is a view similar to FIG. 1 but showing an airflow path of ambient air for heating the air around the pellet stove in accordance with an exemplary embodiment of the present invention;

[0027] FIG. 3 is a fragmented perspective view showing the construction of an inner cylindrical wall of a cyclone combustion burner and the disposition of exemplary air jet holes therein in accordance with an exemplary embodiment of the present invention;

[0028] FIG. 4 is a side view of an inner cylindrical wall illustrating a transverse angle of air jet holes with respect to

the transverse axis of the inner cylindrical wall in accordance with an exemplary embodiment of the present invention;

[0029] FIG. 5 is a top view of an exemplary inner cylindrical wall illustrating a tangential angle of the air jet holes with respect to the curvature of the inner cylindrical wall in accordance with an exemplary embodiment of the present invention;

[0030] FIG. 6 is a schematic sectional view of a cyclone combustion burner illustrating a cyclone effect of the combustion zone and the separation of suspended particles therein and its precipitation into the fuel bed in accordance with an exemplary embodiment of the present invention;

[0031] FIG. 7 is a perspective view showing the construction of an exemplary support tray and ash discharge augers in accordance with an exemplary embodiment of the present invention;

[0032] FIG. 8 is an end view of an exemplary support tray showing the drive of the augers and its connection to a motor drive shaft in accordance with an exemplary embodiment of the present invention;

[0033] FIG. 9 is a plan view illustrating the construction of a user interface pad in accordance with an exemplary embodiment of the present invention;

[0034] FIG. 10 is a block diagram illustrating the construction of an exemplary controller and its associated component parts within a pellet burning stove constructed in accordance with an exemplary embodiment of the present invention;

[0035] FIG. 11 is a simplified schematic view wherein an exemplary cyclone combustion burner modified for coupling to other heating devices and wherein a cyclone chamber is mounted horizontally for coupling to existing air-to-air or liquid heat exchange systems, or to absorptive chilling devices, thermoelectric, thermophoto-voltaic generators, and heat engines to provide thermal energy for their specific application in accordance with other exemplary embodiments of the present invention;

[0036] FIG. 12 is another exemplary embodiment of the application as shown in FIG. 11 but wherein the two cyclone gasifying combustion burners are separated from one another;

[0037] FIG. 13 is a schematic illustration, partly in section, illustrating a further application wherein the fuel bed is replaced by a gas burner which is supplied gas from another source in accordance with an exemplary embodiment of the present invention; and

[0038] FIG. 14 is a schematic illustration wherein an exemplary burner is incorporated in a hot air or hydronic hot water producing furnace, herein provided with a solid fuel supply system, in accordance with an exemplary embodiment of the present invention.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0039] The present invention may be described herein in terms of various systems, devices, components and processing steps. It should be appreciated that such systems, devices, components and steps may be realized by any

number of structural components configured to perform the specified functions. For example, the present invention may employ various electronic control devices, venting systems, flow controls and the like, which may carry out a variety of functions under the control of one or more control systems, microprocessors or other control devices. In addition, the present invention may be practiced in any number of burner contexts and the exemplary embodiments relating to a system and method for a high-efficiency cyclone gasifying combustion burner as described herein are merely a few of the exemplary applications for the invention. For example, the principles, features and methods discussed may be applied to any fuel burning application or process.

[0040] Referring now to FIGS. 1 and 2, in accordance with an exemplary embodiment, a solid fuel heating device 10 having a combustion chamber 12 in which an exemplary cyclone gasifying combustion burner 11 is configured to produce thermal energy is illustrated. The cyclone combustion burner 11 is disposed proximate to the bottom of a combustion chamber 12 and/or otherwise proximate to a fuel bed 25. In an exemplary embodiment, combustion air indicated by arrows 13 is drawn through a manifold chamber 14 defined between an outer steel cylindrical wall 15 and an inner steel cylindrical wall 16. The inner steel cylindrical wall 16 can be provided with angularly oriented or otherwise inclined air jet holes in various manners and configurations as will be described later. In the exemplary embodiment, air entering the manifold chamber is heated and drawn into a reaction zone of the burner 11 through the air jet holes and is convected in the direction of arrows 17 towards an exhaust flue 18, such as by a combustion fan 68, which can be located internally to heating device 10 or proximate the exterior of device 10. While drawing of air can provide improved operation, such air can also be suitably blown or otherwise forced into the reaction zone in other exemplary embodiments.

[0041] As shown in FIG. 2, an exemplary heat exchange arrangement in the form of hollow pipes 19 can be disposed towards the top end of the combustion chamber 12 and heated by the flow of hot air as indicated by arrow 17. Ambient air, as indicated by arrows 20, is circulated through the hollow pipes 19 by a fan 21 mounted in a side wall of the heating device, or any other convenient location such as proximate the hot air exhaust area, to exhaust heated air from the pipes 19 into the ambient air, as indicated by arrow 22, whereby to heat the surrounding area of the solid fuel heating device 10. Fan 21 can be configured in various locations for circulating ambient air through pipes 19, with such pipes 19 being arranged in various manners for discharging heat to the surrounding area.

[0042] The solid fuel heating device 10, as herein illustrated in the exemplary embodiment, comprises a biomass pellet, fuel and/or grain-fed space heating stove and can include a hopper 23 configured for storage of fuel sources, such as solid fuel pellets 24, for example. Hopper 23 can comprise various sizes, shapes and configurations for storage of fuel. In accordance with an exemplary embodiment, the feed pellets are fed into a fuel bed 25 of the cyclone burner 11 by an auger 26 feeding a chute 27. In the exemplary embodiment, the solid fuel, pellets 24 entering the cyclone burner 11 are projected into the fuel bed 25 by gravity and supported by a support mechanism in the form of a support tray 28 fixedly secured under the bottom open

end of the inner cylindrical wall 16. An ash collecting tray 29 is removably secured under this support tray 28 and accessible through a door 30. It is pointed out that the solid fuel pellets and grains 24 could also be fed from the bottom or the side of the unit or any other configuration for providing fuel pellets and the like onto fuel bed 25. For example, rather than hopper 23 and/or auger 26, any other mechanisms or systems for conveying materials can be suitably implemented.

[0043] Referring now to FIGS. 3 to 6, in accordance with exemplary embodiments, an inner cylindrical wall 16 of the cyclone combustion burner 11 is illustrated. As herein shown, an exemplary inner cylindrical wall 16 is provided with a series of angulated air jet holes 31 of substantially predetermined diameter and disposed at substantially predetermined locations therein to create a uni-directional cyclone to create a reaction zone 33 within the combustion chamber. For example, an exemplary cyclone-like effect is illustrated by reference numeral 32 in FIG. 6. This cyclone 32 is oriented in the reaction zone 33 in an area above the fuel bed 25 and extending close to the top open end 34 of the inner cylindrical wall 16. By angulating the air jet holes, the cyclone path can be oriented to achieve optimum separation of suspended particles to facilitate sufficient retention time to burn the combustion gases. This reaction zone 33, defined by the inner cylindrical wall 16, can be of a substantially predetermined length depending on the size of the cyclone combustion burner 11, among other parameters and criteria.

[0044] As shown in FIG. 3, in accordance with an exemplary embodiment, the air jet holes 31 are disposed in groups on at least two inclined axes 35, such as, for example, the three groups of these holes shown in FIG. 3; however, this disposing of groups may vary depending on the diameter of the inner cylindrical wall. Moreover, while at least two inclined axes 35 are desirable, using a single inclined axis 35 can also be provided in other exemplary embodiments.

[0045] In accordance with the exemplary embodiment of FIG. 3, each group of the air jet holes 31 comprise four holes, but again this may vary depending on the size of the cyclone burner for applications at the commercial and industrial scale. Also, the holes can be offset from one another and not necessarily be equidistantly spaced apart provided that they create a uni-directional cyclone which achieves the desired result of increasing at least one of the residency time, turbulence, and/or the mixing of oxygen and volatile gases to substantially combust the gases drawn into the reaction zone 33. In addition, the configuration of air jet holes 31 can also cause suspended particles to gravitate to the fuel bed. It should be noted that the relative sizes, number, spacing and linearity of the holes 31 within an axis 35 can suitably configured in various manners to facilitate the cyclone effect. Therefore, although FIG. 3 shows an exemplary pattern for the angulated air jet holes, it is conceivable that other suitable patterns may produce a similarly satisfactory result.

[0046] As shown in FIGS. 4 and 5, in accordance with an exemplary embodiment, each of air jet holes 31 can be disposed at a tangential angle 36 (e.g., see FIG. 5) with respect to the curvature of the inner cylindrical wall 16. Holes 31 can also be oriented at a transverse angle 37 (e.g., see FIG. 4) extending in the direction of the open top end 34. While in accordance with the exemplary embodiments each

of holes **31** may be configured with substantially the same tangential angle **36** and/or transverse angle **37**, in accordance with other exemplary embodiments, one or more of holes **31** can also be configured with different tangential angles **36** and/or transverse angles **37**. In accordance with an exemplary embodiment, the negative pressure within the combustion chamber **12** of the solid fuel heating device **10** draws the combustion air through the manifold **14** and through the one or more angled air jet holes **31** at a low pressure wherein the air/fuel ratio is from about 6:1 to 10:1, or other like air/fuel ratio sufficient to create a high velocity cyclone within the reaction zone **33** to provide one or more of the intended functions.

[0047] In accordance with an exemplary embodiment, the tangential angle **36** is in the range of between approximately 15° to 89° with respect to the curvature of the inner cylindrical wall **16**. This angle is calculated from a tangent **38** of the curved outer surface **39** at the point of entry of the air jet hole **31** into the inner cylindrical wall **16**, as illustrated in FIG. 5. For example, for a 4 inch diameter inner cylindrical housing, this angle can be between approximately 55° and 65°, e.g. approximately 61°. The transverse angle **37** is in the range of approximately 1° to 15° or more with respect to the transverse axis **40** as illustrated in FIG. 4, such as at an angle of approximately 13°. However, holes **31** can be configured at any tangential and/or transverse angle configured to generate air flow configured to create a cyclone-like effect and/or suspend particles.

[0048] The angular orientation of these air jet holes **31** creates the cyclone combustion air flow within the reaction zone **33** inside the inner cylindrical wall and causes the combustion gases released from the fuel bed to follow a cyclone path with the combustion air whereby the residency time of these combustion gases is increased to achieve substantially total combustion thereof. This increase in residency time within the combustion zone **33** can also cause the suspended particles, herein designated by reference numeral **41**, to be projected against the inner surface **42** of the inner cylindrical wall **16** by the centrifugal force of the cyclone and agglomerate with other particles **41** to increase their molecular weight and thereby gravitate to the fuel bed **25**. For example, particles at the center of the cyclone **32**, herein illustrated by reference numeral **41**, can also precipitate towards the fuel bed since the center of the cyclone can comprise an area of entrapment. These particles can collect at the bottom of the fuel bed in the support tray **28** below the combustion zone **25** of the fuel bed **25**. Accordingly, this cyclone action in the reaction zone results in a substantial total reduction of the emission of pollutants into the atmosphere.

[0049] As shown in FIGS. 3 and 4, one or more other air jet holes, such as holes **45**, can be provided in the inner cylindrical housing whereby to admit combustion air into the fuel bed **25**. Such holes **45** may have minimal to no inclination as they feed combustion air to the bed. The number of these holes will depend on the desired air fuel ratio and as above-indicated, this fuel ratio is about 6:1 to 10:1, such as approximately 8:1, whereas with conventional pellet stoves, the fuel is burned at a fairly high ratio of 35:1 or more.

[0050] A problem with burning pellet fuel, such as corn, wood pellets, etc., at high temperature is that the mineral

elements in these pellets fuse, deform to a semi-liquid state and crystallize to form a slag like clinker deposit within or adjacent to the fuel bed combustion area. Usually, these conventional wood pellet stoves operate at an air to fuel ratio of at least 35:1 or more, thus the air blowers need to operate at a high rate of speed. This high rate of speed causes ash to fly out of the burner, thereby affecting the operation of the fans and motors and entraining in the atmosphere fly ash, volatiles, particulates and substantially increased levels of NOX from excess combustion air. With burner **11**, it can be said that the system is an air-starved system and accordingly, burner **11** burns the solid fuel at a lower temperature, substantially below the fusion point of the inorganic elements which may be present and which make up the ash which is also metered out of the fuel bed area and into an ash holding area. Solid fuels have different mineral contents and when properly controlled and subjected to a balanced air to fuel ratio and ash management system, which substantially influence the fuel bed characteristics and reaction zone cyclone, and it has been found that substantially no clinkers are formed.

[0051] It is pointed out that the inner diameter of the inner cylindrical wall **16** may vary within a minimum of approximately 1 inch to 48 inches or more depending on the application of the burner be it residential, commercial or industrial. The height of the inner and outer cylindrical walls can also vary between a minimum of approximately 2 inches to 48 inches or more. The air jet hole diameter may also vary from approximately 1/16 of an inch to 6 inches or more. The air jet holes **31** can also be spaced apart at a predetermined distance from one another, depending on various design criteria.

[0052] As the solid particles and ash collect within the bottom end of the fuel bed **25** below the combustion zone **25** and into the support tray **28**, such particles and ash can be automatically removed from the bottom of the fuel bed as will now be described with reference to exemplary embodiments illustrated in FIGS. 6 to 8. For example, in accordance with an exemplary embodiment, a support tray **28** can comprise an elongated shallow rectangular housing **50** in which there is disposed one or more auger screws **51**, such as the three screws **51** illustrated in FIG. 7, that are coupled to a drive shaft **52** through inter-engaging gears **53**. A drive device, herein an electric motor **54**, connects to the drive shaft **52** and rotates the one or more auger screws at a controlled speed rate. The rate of speed of the motor **54** is determined by a controller **60**. The housing **50** has a top wall **54** with an opening **55** which is disposed under the inner cylindrical wall **16** and this open area **55** defines the fuel bed. The combustion zone **25** of the fuel bed **25** is an area above this fuel bed once the fuel bed has been lit and the combustible material has established the combustion zone **25**. By rotating the auger screws **51** at a predetermined speed, it creates a "bubbling effect" in the fuel bed improving combustion of the solid fuel particles and causing the ashes produced to percolate, to the bottom of the fuel bed area, wherein the auger screws displace the ashes towards an open bottom end section of the housing which constitutes an ash discharge section **56** where ashes are discharged within an ash collecting tray **29** positioned thereunder, as illustrated by reference numeral **57**. Although housing **50** can comprise auger screws **51** configured to induce a "bubbling effect", any other mechanism or devices, such as vibrating screens or conveyors, can also be suitably incorporated. Moreover,

rather than a housing 50 and screw 51 configuration, support tray can also include a grating configuration for holding fuel within fuel bed 25.

[0053] Referring now to FIGS. 9 and 10 in accordance with exemplary embodiments, there will be described the operation of an exemplary controller 60. This controller 60 is connected to a user interface pad 61 that is provided with an internal memory 62 (see FIG. 10), and which keypad permits a user to control the operation of the solid fuel biomass pellet heating device 10, such as illustrated in FIGS. 1 and 2. The main controller 60 controls the motor 54 and the fans and inputs operating parameters by sensors, as will be described later. To start the operation of a biomass pellet device 10, as illustrated in FIGS. 1 and 2, a measured quantity of pellets 24 are placed in the fuel bed 28 along with a starter fluid, and this is ignited by the user and the door of the biomass burner device is closed, or the pellets are automatically fed to the burner and ignited by an ignition device, to create an initial fuel bed. The user then selects a desired mode of operation of the device 10 by inputting desired parameters into the controller by the use of the interface pad 61. The interface pad 61 can also be provided with pressure sensitive switches 62 whereby to set the fuel feed and speed of the exhaust fan and consequently the quantity of air admitted into the combustion zone of the cyclone burner, whereby to increase or decrease the temperature in the combustion chamber 12 and consequently the temperature of the heated air released by the biomass pellet device through the heat exchanger located above the flame which is also regulated by a separate fan. All of the operating parameters step up or down, to maintain optimum performance levels, according to the desired heat performance required of the device. Additionally the entire system can operate from a remote thermostat to regulate all of these operating parameters according to what the thermostat is set to. Ash control switches 63 can also be provided to fine-tune the ash evacuation rate and this is inputted into the controller which regulates the speed of the motor which drives the auger screws. Output temperature control switches 64 are also provided to set a desired BTU output of the pellet stove. Through the software of the controller, the type of fuel and substantially ideal operating conditions of the device are regulated and maintained.

[0054] As shown in FIG. 10, an exemplary controller 60 is provided with input signals from a low temperature sensor 65 that senses the temperature of the heating device 10 and it is conveniently located on a wall of the heating device. The controller 60 also monitors input signals from an operational thermo sensor 66 which indicates that a flame is present in the burner chamber. A high temperature sensor 67 can also be conveniently located on the outside, back wall of the combustion chamber 12 to sense the temperature thereof. For example, if the sensor 67 detects a predetermined high temperature signal, the controller 60 shuts off the fuel feed auger that delivers the biomass fuel pellets to the fuel burner fuel bed, thus commencing an orderly automatic shutdown of the device 10. Accordingly, the controller modulates the operation of the system to maintain a desired temperature output.

[0055] As also shown in FIG. 10, the controller controls the speed of the combustion fan 68, which can be located within heating device 10 as illustrated in FIG. 1, or otherwise outside or otherwise in flow communication to facili-

tate intake and exhaust air. Controller 60 can also control the speed of the convection fan 21 that is used to force the air through the heat exchangers 19. As mentioned hereinabove, controller 60 can also control the ash auger motor 54 that evacuates the ashes depending on the operating parameters of the system and high or low ash fuel type. A power supply 69 provides the 12 VDC power for the controller and interface.

[0056] In accordance with an exemplary embodiment, the user interface pad 61 is also provided with switches 70 to condition the controller to operate within a stored programmed mode of operation depending on the type of fuel being fed to the burner. A red stop switch 71 is provided to shut down the operation of the heating device. A manual feed switch 72 is also provided to feed fuel to the combustion bed during the priming cycle at start-up. Additionally this can be regulated automatically from a thermostat prior to automatic ignition of the fuel present in the burner.

[0057] Digital numeric display windows display a number indicative of the set parameters inputted by the user person by the switches 62, 63 and 64. These display windows will display numbers such as 1 to 5 with the highest number indicating the highest feed rate or fan speed. When the operator selects a desired operation of the stove, normally a setting from 1 to 5, each of these settings is associated with a program fuel feed rate with corresponding air feed rates for optimum efficiency in the operation of the unit. As the unit operates the controller senses the operating parameters thereof and automatically adjusts the elements that it controls such as fan speed and ash evacuation rates, and the convection fan 21 is adjusted so that the output air temperature of the stove is substantially the one selected by the user. The sensors also provide a safety system for the heating device by monitoring the temperature of the combustion chamber and the exhaust temperature. The controller and/or sensors can also be configured to detect if there is no longer a fire in the burner and will turn the heating device off once the unit has cooled down to a pre-set temperature.

[0058] Although the application of the cyclone burner 11 is herein described with respect to an application of a wood and biomass pellet and whole grain burning stove, it is pointed out that this burner can be coupled to existing air-to-air and liquid heat exchange systems to provide thermal energy for their respective applications and heat exchanger surfaces or their combustion chambers. As example of applications, the cyclone burner can be coupled to boilers or hot air furnaces and can be mounted at any suitable angle as is required, examples include vertically or horizontally, as will be described later. As previously described, the size of the cyclone burner can vary greatly and its dimensions can be substantially increased for residential, commercial, and industrial thermal heat transfer applications. It is envisaged that such a burner can replace existing fuel burners such as oil or gas burners, and this technology can be scaled up from current levels, for biomass pellet and whole grain applications, to over 60 million BTUs or more depending on the required application. In such larger applications, and as previously described, more air jets can be provided to allow oxygen to catalyze with the volatile gases which are entering the burner from the gasification chamber.

[0059] It is also pointed out that in the pellet stove application because the system is operating at a low air-to-

fuel ratio, most ash particles that leave the cyclone burner will not be drawn out or up into the exhaust or flue but will precipitate within the lower part of the device where the ash collecting compartment is located. Accordingly, there are virtually no volatilized organic compounds emitted into the atmosphere with the exhaust and complete combustion of the gases therefore takes place in the cyclone burner and complete containment of the particulate is substantially accomplished.

[0060] As shown in FIG. 6, a deflector bracket **80** may be secured to the cyclone burner and project within the reaction zone **33**. This deflector **80** can be formed by a strip of stainless steel or other suitable steel material and provided with a hook end **81** to hook onto the top edge **82** of the burner, or any other configuration for connecting a deflector to a burner wall. The deflector projects inside the inner wall **42** a predetermined distance and is sloped in a bottom end section to form a deflecting end **83**, whereby fuel pellets or grains, such as shelled corn, when projected into the burner by the chute **27**, will be deflected into the fuel bed to prevent such fuel from forming an uneven fuel bed. The deflector is secured in alignment with the chute **27**. This deflection is derived and positioned to cause minimum interference with the cyclone **32**. It is also conceivable that a deflector could also be coupled to the feeding chute, or any other like manners for deflecting fuel into the bed; deflector **80** as shown herein is simple to construct and effective, but can certainly be configured in various other sizes, shapes, angles and configurations.

[0061] The following is a summary of test results obtained on a pellet stove equipped with the "close coupled gasification" cyclone burner of the present invention and tested by the McGill University Energy and Environmental Research Laboratory.

#### TEST RESULTS

[0062] Three different biomass fuels were used for testing: corn, bark, and wood pellets. Each biofuel was tested four times in order to verify data repeatability at two feed rates of 2.5 lbs/hr and 3.0 lbs/hr. Tests were performed according to ASTM and Environment Canada/Quebec testing protocols (e.g., standards concerning the following articles were applied: B.315, articles 8, 10, 11, 12, 24, 27, 45, 65, 67). Collection of data was conducted after achieving a steady-state. Gas concentration measurements (VOC, CO, CO<sub>2</sub>, NO<sub>x</sub>) were taken at a rate of 1 ft<sup>3</sup>/min. In addition, samples of solid particulates in the exhaust gas and residual ashes were collected to determine mass concentration, chemical composition and morphology.

#### MAIN OBSERVATIONS

[0063] Negligible amount of solid particulates were found in the exhaust gas.

[0064] Less than detectable amount of VOCs were found.

[0065] NO<sub>x</sub> concentrations were below acceptable emission standards.

[0066] In most cases CO concentration was within a range of 11-25 ppm/hr.

[0067] Exhaust temperature changed between 130 and 150° C.

[0068] Corn yielded lowest CO emissions

[0069] The following hierarchy of the biomass fuel was established at lower feeding rate of 2.5 lbs/hr: bark>wood>corn.

[0070] The following hierarchy of the biomass fuel was established at a higher feeding rate of 3.0 lbs/hr: corn>bark>wood.

[0071] It can therefore be concluded that with the construction of a cyclone burner having air jet holes oriented to create a particle suspension, reaction zone in the burner chamber to increase the residency time of combustion gases and particulate material, substantially all of the combustion gases are burned and substantially all the particulate material precipitates into an ash collecting tray. The burner is also operated at low pressure (air tight sealed) with low excess combustion air which lowers the fuel bed temperature (air starved) which substantially prevents the fusion of inorganic elements within the fuel bed and the formation of slag deposits. Independent testing has shown that the emission levels of volatile organic compounds (VOC), particulates and fly ash, and the level of nitrogen oxides (NO<sub>x</sub>), is substantially reduced below acceptable regulated levels.

[0072] Referring now to FIG. 11, in accordance with other exemplary embodiments, there is shown a modification of the cyclone gasifying combustion burner for different applications whereby the burner can be coupled to boilers or hot air furnaces and can be mounted either vertically or horizontally or angularly. As shown in FIG. 11, the burner **11** can be constructed as previously described with the exception that the fuel bed **25** is not fed from above but from a supply conduit **80** also provided with an auger screw **81** to transfer the solid biomass fuel pellets **24** from a hopper **82**. Various other conventional configurations and methods for feeding fuel bed **25** can also be implemented in various other exemplary embodiments. The supply conduit **80** has an open end **83** formed in the inner cylindrical wall **16** of the combustion burner housing **11**, herein mounted vertically. The opening **83** is positioned above the fuel bed **25** and below the series of air jets **31**.

[0073] The open top end **84** of the vertical combustion burner housing **11** is coupled to a further combustion burner housing **11'** mounted horizontally. The further combustion housing also has an inner cylindrical wall **16'** provided with air jet holes **31'** therein and its manifold **14'** is connected to a fan **85** to provide air pressure to create the cyclone within the combustion burner housing **11'**. As herein shown each of the manifold chambers **14** and **14'** are connected and coupled together whereby the fan **85** is sufficient to draw air through the air jet holes **31** of the vertical combustion burner housing **11**. However, a further fan may be connected to the manifold chamber **14** which may be independent from the manifold chamber **14'** and this further fan is illustrated schematically by reference numeral **86**. Although not shown, the ash collector as described hereinabove with reference to FIGS. 7 and 8 would be connected to the bottom end of the vertical combustion burner **15**.

[0074] As herein shown, the further combustion burner **11'** has a closed end wall **87** and an opposed open end **88** for the flame **89** to exit and provide a source of thermal energy. The further combustion burner housing **11'** is mounted substantially transversely to the vertical burner and the inner

cylindrical walls about these burners are connected together in communication to form a continuous internal combustion chamber. An igniter device **90** may also be provided to start a flame within the horizontal combustion burner housing **11'**. Of course, although not shown, the fuel bed **25** can be ignited as previously described. Because the hopper **82** is located exteriorly of a boiler or furnace, to which this burner is coupled, the hopper can be continuously supplied with biomass fuel pellets to provide continuous operation, if necessary to do so.

[0075] FIG. 12 shows another exemplary embodiment similar to that illustrated in FIG. 11 but wherein the combustion burner housing **11'** is not directly coupled to the vertical combustion burner housing **11**. As herein shown, the horizontal combustion burner housing **11'** has an open rear end **91** which is coupled by conduit **92** to a gas collecting chamber **93** and into which are fed combustion gases from the fuel bed **25** flowing out of inner cylindrical wall **16** through a further conduit **94** and from the top end **95** thereof through a feed auger screw **96** which connects to the bottom of the collecting chamber **93**. Pellets are fed from a hopper **97** and a feed auger **98** into the bottom of the gas collecting housing **93** onto the auger screw **96** where they are transported and released into the fuel bed **25** is herein shown. This hot combustible gas in the collecting chamber maintains a flame extending into the conduit **92** and into the inner cylindrical chamber of the combustion housing **11'** where it is mixed with additional air within the cyclone therein. A blower **99** is provided to create a cyclonic combustion air flow within the horizontal combustion burner housing **11'**. A further burner **100** is also connected to the manifold chamber **14** of the vertical combustion burner housing **11**. The ash collecting tray **50** is also connected to the bottom of the vertical chamber if deemed necessary but the blower **99** may be sufficient to create a negative pressure within the vertical combustion burner housing **11** to create the cyclonic air flow path within its inner cylindrical wall.

[0076] As previously described, the disposition of the air jet holes within the inner cylindrical wall can suitably create a cyclone-like flow in a reaction zone in the inner cylindrical wall and it is also conceivable that combustion gases may be applied directly within the inner cylindrical wall below the cyclone path to mix therewith, whereby to increase the residency time of the gas for substantially complete combustion thereof. Accordingly, FIG. 13 shows another exemplary embodiment where the fuel bed is replaced by a combustion gas supply **101** connected to an injector **102** secured to the burner housing **11** adjacent a bottom end thereof. The bottom end of the burner is herein shown having a bottom end **103** but if the gas being burned is one that contains suspended particles which would collect at the bottom end of the burner **11** then a collecting tray such as the tray **50** could be mounted at this bottom end.

[0077] In this exemplary embodiment, a regulator device **104** is mounted in the supply line **105** and may be controlled by a controller such as the one described hereinabove. An igniter **106** provides for the ignition of the injector **107**. A fan **108** provides air under pressure to the manifold **14** to create the cyclone **32**.

[0078] Referring now to FIG. 14, there is shown a further embodiment wherein an exemplary high efficiency cyclone gasifying combustion burner is incorporated into a hot air

furnace **120**. For example, a large hopper structure **121** is mounted next to the furnace **120** and supplies solid biomass fuel pellets or other granular particles **122** to the combustion burner **11** by means of a chute, not shown herein but similar to chute **27** as illustrated in FIG. 2. The supply of pellets to the chute is provided via a screw conveyor **123**, the speed of which is controlled by a controller modulating the speed of the motor **124** which drives the auger screw, not shown, within the screw conveyor **123**. The controller is coupled to a thermostat whereby to control the burner **11** within the furnace **120** in a manner as previously described. It is also pointed out that the furnace **120** may be an industrial furnace of large dimension. Also, the solid combustion fuel may be coal which is fed to the burner **11** from the hopper **121**.

[0079] As described above, an exemplary high efficiency cyclone gasifying combustion burner can be incorporated with several devices requiring a thermal energy source to heat an area as in space and central heating, such devices may have applications for processing materials, for cooling by an absorptive chilling device to reduce the temperature of an area, for processing materials, to produce electricity through the thermal expansion of gases which produce mechanical force, as in steam turbines, and as a source of thermal energy in thermoelectric and thermo photovoltaic devices for the generation of electricity, and/or as a thermal heat source for a heat engine.

[0080] The present invention has been described above with reference to various exemplary embodiments. However, those skilled in the art will recognize that changes and modifications may be made to the exemplary embodiments without departing from the scope of the present invention. For example, the various operational steps, as well as the components for carrying out the operational steps, may be implemented in alternate ways depending upon the particular application or in consideration of any number of cost functions associated with the operation of the system, e.g., various of the component and methodologies and/or steps may be deleted, modified, or combined with other components, methodologies and/or steps. For example, various of the systems and devices within controller **60**, can suitably be modified, removed or replaced. These and other changes or modifications are intended to be included within the scope of the present invention, as set forth in the following claims.

1. A cyclone gasifying combustion burner comprising a combustion housing defined by an inner cylindrical wall surrounded by a manifold chamber configured with an combustion air inlet, said inner cylindrical wall having air jet holes therein of substantially predetermined diameter and disposed at a substantially predetermined angle to create an air cyclone flow in a reaction zone in said inner cylindrical wall spaced above a lower air starved flaming pyrolysis gasifying fuel bed thereof whereby to increase at least one of the residency time, turbulence, mixing of oxygen, and volatile gases for substantially complete combustion of gases within said reaction zone.

2. A cyclone gasifying combustion burner as claimed in claim 1 wherein said gasifying fuel bed is supported on a platform having a controllable discharge device for the automatic removal of ash accumulating in a lower section of said fuel bed.

3. A cyclone gasifying combustion burner as claimed in claim 1 wherein said air jet holes are disposed by spacing apart at substantially predetermined distances and in series

on at least one substantially predetermined inclined axis to create a unidirectional combustion air cyclone flow in said reaction zone.

4. A cyclone gasifying combustion burner as claimed in claim 3 wherein said predetermined angle of said air jet holes is defined by a first tangential angle with respect to the curvature of said inner cylindrical wall.

5. A cyclone gasifying combustion burner as claimed in claim 4 wherein said predetermined angle of said air jet hole is further defined by a second transverse angle with respect to a transverse axis of said inner cylindrical wall and angulated in the direction of an open end of said inner cylindrical wall.

6. A cyclone gasifying combustion burner as claimed in claim 3 wherein said suspended particles are projected by said air cyclone flow against an inner surface of said inner cylindrical wall wherein at least some of said particles will agglomerate with other particles and thereby increase the molecular weight thereof and gravitate to said fuel bed and thereby substantially reducing the emission of pollutants into the atmosphere.

7. A cyclone gasifying combustion burner as claimed in claim 4 wherein said tangential angle is in the range of between approximately 15° to 89° with respect to the curvature of said cylindrical wall.

8. A cyclone gasifying combustion burner as claimed in claim 7 wherein said tangential angle is at approximately 60 degrees.

9. A cyclone gasifying combustion burner as claimed in claim 5 wherein said transverse angle is in the range of approximately 1° to 15° from said transverse axis.

10. A cyclone gasifying combustion burner as claimed in claim 9 wherein said transverse angle is approximately 13 degrees.

11. A cyclone gasifying combustion burner as claimed in claim 1 wherein said combustion burner is a low pressure burner having an air/fuel ratio of from about 6:1 to 10:1.

12. A cyclone gasifying combustion burner as claimed in claim 1 wherein said predetermined diameter is within the range of from about 1 to about 48 inches with respect to the height of said inner circumferential wall which height is from about 4 to about 48 inches and in which said reaction zone is established.

13. A cyclone gasifying combustion burner as claimed in claim 1 wherein said predetermined diameter of said air jet holes is from about 1/16 to about 2 inches.

14. A cyclone gasifying combustion burner as claimed in claim 1 wherein said solid fuel is a biomass solid fuel in a particle, granular, pellet form or whole grain or seed or coal form

15. A cyclone gasifying combustion burner as claimed in claim 1 wherein said series of inclined air jet holes extend in said inner cylindrical wall from above said fuel bed whereby said fuel bed is substantially starved from combustion air to lower the temperature of combustion of said flaming pyrolysis fuel bed below the fusion point of inorganic elements that may be present within said fuel bed to prevent agglomeration within said bed.

16. A cyclone gasifying combustion burner as claimed in claim 1 wherein said reaction zone has a length sufficient to provide said substantially complete combustion of said combustion gases and the containment of said particles to substantially eliminate the emission of pollutants.

17. A cyclone gasifying combustion burner as claimed in claim 15 wherein there is further provided additional air jet holes in said inner cylindrical wall and spaced from said series of inclined air jet holes to activate said flaming pyrolysis gasification combustion zone.

18. A cyclone gasifying combustion burner as claimed in claim 1 wherein said air jet holes in each said series are spaced at a substantially predetermined distance from one another.

19. A cyclone gasifying combustion burner as claimed in claim 18 wherein there is provided a substantially predetermined number of series of said inclined air jet holes dependent upon the diameter and height of said inner cylindrical wall, said series of inclined air jet holes being equidistantly spaced about the circumference and height of said inner cylindrical wall.

20. A cyclone gasifying combustion burner as claimed in claim 19 wherein there are at least two series of inclined air jet holes for a 4 inch diameter inner cylindrical wall, said air jet holes having a diameter of about 1/16 inch.

21. A cyclone gasifying combustion burner as claimed in claim 2 wherein said platform is a support tray having a solid fuel support section and an ash discharge section, at least two auger screws rotatably supported in said tray and extending from said solid fuel support section to said discharge section, and a drive device to rotate said auger screws to percolate smaller particles of ash to the bottom of said fuel bed, said ash material at the bottom of said fuel bed support section being transported by said auger screws to said discharge section.

22. A cyclone gasifying combustion burner as claimed in claim 21 wherein said drive device to rotate is an electric motor drive coupled to said auger screws, said electric motor drive being controlled by a controller to discharge said ash material at a controlled rate dependent on the percentage of ash in the fuel and the operating parameters of said cyclone combustion burner, whereby to inhibit the release of fly ash during the combustion process of solid fuel and reduce slag deposition and fused minerals and to control the level of said fuel bed in tandem with each other for optimal performance.

23. A cyclone gasifying combustion burner as claimed in claim 2 in combination with a heating device having a combustion chamber in which said burner is incorporated, a heat exchanger in said combustion chamber, an air displacement device to create a negative pressure in said combustion chamber to displace hot air against said heat exchanger and to draw air through said air jet holes in said inner cylindrical wall of said combustion burner, and a controller to control said air displacement means.

24. A cyclone gasifying combustion burner as claimed in claim 23 wherein said heating device is a hot air furnace.

25. A cyclone gasifying combustion burner as claimed in claim 23 wherein said solid fuel is coal.

26. A cyclone gasifying combustion burner as claimed in claim 23 wherein said heating device is a biomass pellet stove and said heat exchanger is comprised of isolated air circulating flow paths in contact with surfaces heated by said hot air in said combustion chamber, and an air circulating device to circulate ambient air through said flow path.

27. A cyclone gasifying combustion burner as claimed in claim 26 wherein said platform is a support tray having a solid fuel support section and an ash discharge section, at least two auger screws rotatably supported in said tray and extending from said solid fuel support section to said

discharge section, and a drive device to rotate said auger screws to cause ash material at the bottom of said fuel bed support section to be transported to said discharge section, and a solid fuel pellet storage hopper having discharge means to feed solid biomass fuels to said flaming pyrolysis combustion bed, and an exhaust device to exhaust gases from said combustion chamber to atmosphere.

**28.** A cyclone gasifying combustion burner as claimed in claim 27 wherein there is further provided a deflector element extending into said combustion zone to deflect said combustible biomass fuels released in said inner cylindrical wall of said burner from said discharge device to distribute same over said fuel bed to substantially promote an even distribution of said biomass fuels onto said fuel bed.

**29.** A cyclone gasifying combustion burner as claimed in claim 27 wherein there is further provided an ash removal tray positioned under said ash discharge section of said support tray, said ash removal tray being accessible through a door secured in a housing of said biomass stove, said drive device to rotate said auger screws being an electric motor coupled thereto by a gear linkage.

**30.** A cyclone gasifying combustion burner as claimed in claim 27 wherein there is further provided a controller for automatically controlling the operation of said pellet stove, and a user interface pad having a memory and switches to set parameters into said controller relating to a desired mode of operation, and a visual display device.

**31.** A cyclone gasifying combustion burner as claimed in claim 30 wherein said switches comprise combustion fan switches to set the speed of said exhaust means and consequently the quantity of air admitted in said combustion zone to increase or decrease the temperature in said combustion chamber, ash control switches to fine tune the evacuation rate of ashes according to the fuel type selected and percentage of ash present in said fuel type during combustion by adjusting the speed of said drive device to rotate said auger screws, and output temperature control switches to set the BTU output of said pellet stove.

**32.** A cyclone gasifying combustion burner as claimed in claim 31 wherein said controller is provided input signals from a low temperature sensor to sense the temperature of said stove, input signals from an operational thermo sensor to indicate the absence of a fire in said combustion burner, and signals from a high temperature sensor to shut-down the controller when the stove reaches a pre-set temperature.

**33.** A cyclone gasifying combustion burner as claimed in claim 32 wherein said display device is a digital numerical display window which displays a number indicative of the speed of said exhaust device, the speed of said drive device to rotate said auger screws, the speed of said hopper discharge device, and the speed of said air circulating device.

**34.** A cyclone gasifying combustion burner as claimed in claim 33 wherein said controller controls the said devices set by the user interface pad for optimum efficiency and further controls said discharge device of said hopper to set the feed rate of solid particle biomass fuel to said combustion bed based on the set parameters and said input signals from at least some of said sensors.

**35.** A cyclone gasifying combustion burner as claimed in claim 1 wherein said manifold chamber is defined by a concentrically spaced outer cylindrical wall having annular opposed end walls connected to said inner cylindrical wall to form a cylindrical contour chamber.

**36.** A cyclone gasifying combustion burner as claimed in claim 1 wherein said combustion housing is secured in a vertical or horizontal plane, or at a desired angle, and coupled to a combustion chamber of a solid fuel, oil or gas device for residential, commercial or industrial use.

**37.** A cyclone gasifying combustion burner as claimed in claim 1 wherein said combustion housing is a vertical combustion housing having an open top end, a feed device to feed a solid biomass fuel particle, pellet, granular material, grain or seed form to said fuel bed, and a further combustion housing having an inner cylindrical wall surrounded by a manifold chamber, said inner cylindrical wall of said further combustion housing having said air jet holes therein to create a reaction zone therein for the combustion of gases, said further combustion housing having a closed end wall and an opposed open end and being secured adjacent to said closed end wall to an open top end of said combustion housing and extending substantially transversely thereto, said inner cylindrical wall of both said vertical combustion housing and said further combustion housing communicating with one another to form a continuous internal combustion chamber.

**38.** A cyclone gasifying combustion burner as claimed in claim 37 wherein there is further provided an igniter in said inner cylindrical wall of said further combustion housing.

**39.** A cyclone gasifying combustion burner as claimed in claim 37 wherein said feed device to feed said solid biomass fuel is a supply conduit having an open end in said inner cylindrical wall of said vertical combustion housing disposed above said fuel bed, and an auger to transport said biomass fuel in said supply conduit.

**40.** A cyclone gasifying combustion burner as claimed in claim 37 wherein each said manifold chamber is connected to a combustion air pressure generating device.

**41.** A cyclone gasifying combustion burner as claimed in claim 40 wherein said air pressure generating device is a fan.

**42.** A cyclone gasifying combustion burner as claimed in claim 40 wherein each said manifold chamber is interconnected together.

**43.** A cyclone gasifying combustion burner as claimed in claim 1 wherein said combustion housing is a vertical combustion housing having an open top end, a feed device to feed a solid biomass fuel in a particle, granular, pellet or whole or partial grain or seed form to said fuel bed, a further combustion housing having an inner cylindrical wall surrounded by a manifold chamber, said inner cylindrical wall of said further combustion housing having said air jet holes therein to create a reaction zone therein for the combustion of gases and further having an open rear end and an open front end, said open rear end being connected to said open top end of said vertical combustion housing by a conduit for the supply of hot combustible gases released from said open top end and for mixing with an air cyclone of said further combustion housing.

**44.** A cyclone gasifying combustion burner as claimed in claim 43 wherein there is further provided an igniter in said inner cylindrical wall of said further combustion housing.

**45.** A cyclone gasifying combustion burner as claimed in claim 43 wherein said feed device to feed said solid biomass fuel is a supply conduit having an open end in said inner cylindrical wall of said vertical combustion housing disposed above said fuel bed, and an auger to transport said biomass fuel in said supply conduit.

**46.** A cyclone gasifying combustion burner as claimed in claim 43 wherein each said manifold chamber is connected to a combustion air pressure generating device.

47. A cyclone gasifying combustion burner as claimed in claim 46 wherein said air pressure generating device is a fan.

48. A method of substantially reducing at least one of the emission levels of volatile organic compounds (VOC), particulate and entrained fly ash, and the level of nitrogen oxides (NO<sub>x</sub>) during combustion of a solid or gas fuel within a heating device, said method comprising the steps of:

- i) feeding said solid fuel in an open end of a cyclone gasifying combustion burner and onto a flaming pyrolysis fuel bed thereof, disposed below a reaction zone of said burner, said burner having a burner chamber defined by an inner cylindrical wall having a predetermined number of inclined air jet holes of predetermined diameter and height disposed at substantially predetermined locations to create a cyclone air flow within said reaction zone; and
- ii) providing air into said burner chamber through said inclined air jet holes whereby to direct combustion gases from said fuel bed into said reaction zone to mix with said cyclone air flow thereby increasing at least one of the residency time of said combustion gases, turbulence, and mixing of oxygen and volatile gases for substantially complete combustion of gases in said reaction zone.

49. A method as claimed in claim 48 wherein there is further provided the step of (iii) removing said agglomerated particles and ash from said fuel bed in a controlled manner, according to the type of said solid fuel and percentage of ash present in said solid fuel so as to maintain a fuel bed of specific height, to maintain the reaction of flaming pyrolysis and to protect said ash removal augers from excessive temperatures and oxidation.

50. A method as claimed in claim 48 wherein providing air into said burner chamber through said inclined air jet holes is configured to simultaneously precipitate suspended particles against an inner surface of said inner cylindrical wall to cause at least some of said particles to agglomerate with other particles to increase their molecular weight and gravitate to said fuel bed.

51. A method as claimed in claim 49 wherein prior to step (i) there is provided the step of igniting a starter fuel bed below said combustion zone and thereafter enabling a controller for automatic operation of said burner.

52. A method as claimed in claim 51 wherein said cyclone combustion burner is mounted in a heating device having a combustion chamber, said controller effecting the steps of:

- (a) actuating an air displacement device communicating with said combustion chamber to effect said step (i) of drawing combustion air and simultaneously displacing heated air in said combustion chamber against a heat exchanger disposed in said combustion chamber, and
- (b) displacing a medium to be heated through said heat exchange means.

53. A method as claimed in claim 52 wherein said controller further effects the steps of (c) sensing the temperature of said heating device, (d) sensing the temperature of said burner chamber, and (e) sensing a high limit temperature of said heating device to deactivate said heating device if necessary by effecting an orderly shut down of said heating device.

54. A method as claimed in claim 52 wherein said controller further effects the steps of controlling the discharge of said solid fuel particles from a hopper and into said fuel bed.

55. A method as claimed in claim 52 wherein said controller further comprises the step of automatically adjusting the operational parameters of said heating device in accordance with selected programmed input signals received from a user interface pad according to a fuel type being selected for combustion.

56. A method as claimed in claim 48 wherein said heating device is one of a domestic/commercial and industrial hot air furnace, a boiler or a liquid (fluid) heater.

57. A method as claimed in claim 48 wherein there is further provided the step of agitating a fluidized bed to improve combustion and to percolate particles of ash to the bottom of said fuel bed.

58. A method as claimed in claim 48 wherein there is further provided the step of transporting said ash from said bottom of said fuel bed to a discharge area at a rate according to a selected fuel type and the percentage of ash typically present in said fuel type.

59. A gasifying combustion burner having a housing defined by an inner cylindrical wall surrounded by a manifold chamber configured with an combustion air inlet, said inner cylindrical wall having air jet holes therein disposed at predetermined angles to create an air cyclone flow in a reaction zone in said inner cylindrical wall spaced above a lower combustion gas supply, said cyclone flow in said reaction zone configured for increasing at least one of residency time, turbulence, and mixing of oxygen with volatile gases for substantially complete combustion of gases within said reaction zone thereby substantially reducing the emission of pollutants into the atmosphere.

60. A cyclone gasifying combustion burner as claimed in claim 59 wherein said combustion gas supply is delivered by a gas conduit injector secured to said inner cylindrical wall, and an igniter adjacent to an injection nozzle of said injector.

61. A cyclone gasifying combustion burner as claimed in claim 60 wherein said gas injector has a gas supply line conduit connected thereto and a gas control regulator connected to said gas supply line.

62. A method of substantially reducing the emission levels of any one of volatile organic compounds (VOC), particulate, entrained fly ash and the level of nitrogen oxides (NO<sub>x</sub>) during combustion of a gas, said method comprising the steps of:

- i) supplying a combustion gas below a reaction zone of a cyclone gasifying combustion burner, said burner having a burner chamber defined by an inner cylindrical wall having a substantially predetermined number of inclined air jet holes disposed to create a cyclone air flow within said reaction zone when combustion air is drawn therethrough,
- ii) drawing air into said burner chamber through said inclined air jet holes whereby to draw said combustion gases into said reaction zone to mix with said cyclone air flow thereby increasing at least one of the residency time of said combustion gases, turbulence, and mixing of oxygen with volatile gases for substantially complete combustion of gases in said reaction zone to substantially reduce the emission of pollutants into the atmosphere.

63. A cyclone gasifying combustion burner as claimed in claim 62 wherein said step ii) comprises injecting said combustion gas in said inner cylindrical wall through a gas injector connected to a gas supply line, and regulating the flow of gas in said supply line.