Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2530236 C 2010/03/16

(11)(21) **2 530 236**

(12) **BREVET CANADIEN**
**CANADIAN PATENT**

(13) **C**

(22) Date de dépôt/Filing Date: 2005/12/15
(41) Mise à la disp. pub./Open to Public Insp.: 2007/06/15
(45) Date de délivrance/Issue Date: 2010/03/16

(51) Cl.Int./Int.Cl. *F23C 10/08* (2006.01), *F23B 70/00* (2006.01), *F23C 10/24* (2006.01), *F23C 10/28* (2006.01), *F23L 1/00* (2006.01), *F24B 1/02* (2006.01), *F24H 3/06* (2006.01)

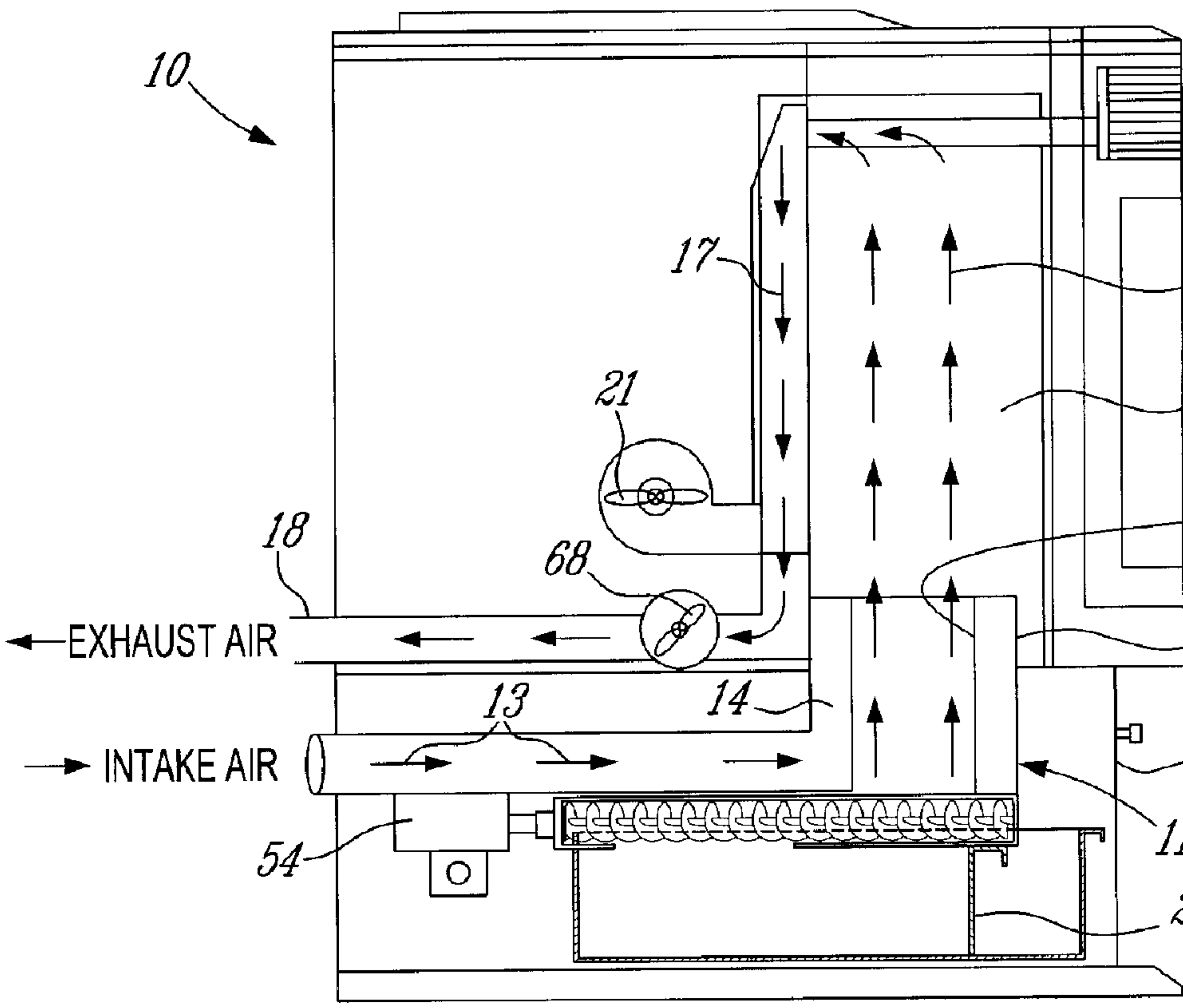
(72) Inventeurs/Inventors:
DRISDELLE, MARK, CA;
LAPOINTE, CLAUDE, CA

(73) Propriétaires/Owners:
DRISDELLE, MARK, CA;
LAPOINTE, CLAUDE, CA

(74) Agent: OGILVY RENAULT LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : BRULEUR A COMBUSTION GAZEIFIANT A CYCLONE HAUTE EFFICACITE POUR LA PRODUCTION D'ENERGIE THERMIQUE ET DISPOSITIFS ET METHODES D'UTILISATION

(54) Title: HIGH EFFICIENCY CYCLONE GASIFYING COMBUSTION BURNER TO PRODUCE THERMAL ENERGY AND DEVICES AND METHOD OF OPERATION




(57) Abrégé/Abstract:
A cyclone gasifying combustion burner and its operation is described. The burner has an inner cylindrical wall with a contour chamber feeding combustion air into the solid fuel support end where a combustible material forms a fuel bed. The inner cylindrical

(57) Abrégé(suite)/Abstract(continued):
wall has at least two series of inclined air jet holes of substantially predetermined diameter and disposed at substantially predetermined locations therein to create a unidirectinal 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 at least one of the residency time, 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. The cyclone combustion burner therefore substantially reduces the emission of pollutants to the atmosphere.

# HIGH EFFICIENCY CYCLONE GASIFYING COMBUSTION BURNER TO PRODUCE THERMAL ENERGY AND DEVICES AND METHOD OF OPERATION

## ABSTRACT

A cyclone gasifying combustion burner and its operation is described. The burner has an inner cylindrical wall with a contour chamber feeding combustion air into the inner cylindrical wall. The burner has an open end and a solid fuel support end where a combustible material forms a fuel bed. The inner cylindrical wall has at least two 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 at least one of the residency time, 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. The cyclone combustion burner therefore substantially reduces the emission of pollutants to the atmosphere.

# HIGH EFFICIENCY CYCLONE GASIFYING COMBUSTION BURNER TO PRODUCE THERMAL ENERGY AND DEVICES AND METHOD OF OPERATION

## TECHNICAL FIELD

[0001] The present invention relates to a high-efficiency cyclone gasifying combustion burner and method of operation which substantially burns all the carbon and volatile gases released from solid fuels preferably from a flaming pyrolytic fuel bed and thereby substantially reduces emission of volatile organic compounds, particulates, fly-ash, nitrogen oxides and other pollutants into the atmosphere.

## BACKGROUND ART

[0002] In our U.S. Patent 6,336,449, we describe a solid fuel burner 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.

[0003] 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.

[0004] 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 ($PM_{2.5}$), nitrogen oxides ($NO_x$) and polycyclic aromatic hydrocarbons (PAH), among others. Smoke from the combustion of wood is present in both inside and outside the home.

[0005] In residential neighbourhoods where wood heating is common, exposure to contaminants from chimney smoke can have a significant impact on health.

[0006] 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.

[0007] 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.

[0008] 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 | $PM_{2.5}$ | Irritation of the respiratory system, aggravation of cardiorespiratory diseases, hastened mortalities |
| Nitrogen oxides | $NO_x$ | 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 |

[0009] The magnitude of these effects depends 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.

[00010] 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.

[00011] 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.

[00012] 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 $CO_2$ (carbon dioxide) during growth as is emitted during combustion.

SUMMARY OF INVENTION

[00013] It is therefore a feature of the present invention to provide a cyclone gasifying combustion burner for use in or coupled to a solid fuel biomass device that

substantially eliminates the above disadvantages of stoves or other solid fuel combustion devices.

[00014] Another feature of the present invention is to provide a method of substantially reducing the emission levels of volatile organic compounds (VOC), particulates and fly ash as well as the level of nitrogen oxide ($NO_x$) during combustion of a solid fuel.

[00015] Another feature of the present invention is to provide a cyclone gasifying combustion burner incorporated into or coupled to a device requiring a thermal energy source and that is automatically controlled in a modulated manner to achieve optimum efficiency.

[00016] Another feature of the present invention is to provide a cyclone gasifying combustion burner having a fuel bed support system that automatically removes ashes from the fuel bed.

[00017] According to a still further feature of the present invention, there is provided a cyclone gasifying combustion burner having the above-mentioned features, and that may be coupled to heating devices for residential, commercial and industrial applications, whereby to replace fossil fuel dependent heating devices.

[00018] According to a still further feature of the present invention, there is provided a heating device incorporating the cyclone gasifying combustion burner of the present invention that achieves significant reduction of greenhouse causing gases.

[00019] A further feature of the present invention is to provide a cyclone gasifying combustion burner wherein 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.

[00020] According to the above features, from a broad aspect, the present invention provides a cyclone gasifying combustion burner comprising a combustion housing defined by an inner cylindrical wall surrounded by a manifold chamber configured with a combustion air inlet. 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 spaced above a lower 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 drawn in the reaction zone and to cause suspended particles to gravitate into the fuel bed and thereby substantially reduce the emission of pollutants into the atmosphere. The air jet holes are disposed spaced apart at substantially predetermined distances and in series on substantially predetermined inclined axes to create a unidirectional combustion air cyclone flow in the reaction zone. The predetermined angle of the air jet holes is defined by a fist tangential angle with respect to a transverse axis to the curvature of the inner cylindrical wall and a second transverse angle, with respect to the transverse axis of the inner cylindrical wall and angulated in the direction of an open end of the inner cylindrical wall. The suspended particles are projected by the air cyclone flow against an inner surface of the inner cylindrical wall wherein at least some of the particles will agglomerate with other particles and thereby increase the molecular weight thereof and gravitate to the fuel bed. The reaction zone has a length which is sufficient to provide the substantially complete combustion of the combustion gases and the containment of the particles to substantially eliminate the emission of pollutants.

[00021] According to a still further broad aspect of the present invention, there is provided a device requiring a thermal energy source in combination with the cyclone combustion burner described hereinabove with the device having a combustion chamber. A heat exchanger is provided in the combustion chamber. Air displacement means creates 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. Means is provided to control the air displacement means.

[00022] According to a further broad aspect of the present invention, the combustion burner is a low pressure burner having an air/fuel ratio of about 6:1 to 10:1.

[00023] According to a still further broad aspect of the present invention, 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 means.

[00024] According to a still further broad 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. The 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 at least one of 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.

[00025] According to a further broad aspect of the present invention, the vertical combustion housing has an open top end. Means 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.

[00026] According to a still further broad aspect of the present invention, 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.

[00027] According to a still further broad aspect of the present invention, there is provided a cyclone gasifying combustion burner having a combustion housing defined by an inner cylindrical wall surrounded by a manifold chamber having combustion air inlet means. 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 at least one of 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.

[00028] According to a still further broad aspect of the present invention there is provided a method of substantially reducing the emission levels of any one of volatile organic compounds (VOC), particulates, entrained fly ash, and the level of oxygen oxides ($NO_x$) during combustion of a gas. The method comprises supplying a combustion gas from below a reaction zone of a cyclone gasifying combustion burner. The burner has 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 creating an air flow 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 at least one of 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.

[00029] According to another broad aspect of the present invention there is still further 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, said inner cylindrical wall having air jet holes disposed at a substantially predetermined angle to create an air cyclone flow in a reaction zone in said inner cylindrical wall spaced above a pyrolysis gasifying fuel bed whereby to increase at least one of the residency time, turbulence, mixing of oxygen and volatile gases for substantially complete combustion of gases drawn in said reaction zone.

BRIEF DESCRIPTION OF DRAWINGS

[00030] A preferred embodiment of the present invention will now be described with reference to the accompanying drawings in which:

[00031] FIG. 1 is a simplified side view, partly sectioned, of a pellet stove heating device and showing the airflow path through the cyclone combustion burner of the present invention and through a heat exchanger chamber of the device and out through a flue conduit;

[00032] FIG. 2 is a view similar to Figure 1 but showing the airflow path of ambient air for heating the air around the pellet stove;

[00033] FIG. 3 is a fragmented perspective view showing the construction of the inner cylindrical wall of the cyclone combustion burner and the disposition of the air jet holes therein;

[00034] FIG. 4 is a side view of the inner cylindrical wall illustrating the transverse angle of the air jet holes with respect to the transverse axis of the inner cylindrical wall;

[00035] FIG. 5 is a top view of the inner cylindrical wall illustrating the tangential angle of the air jet holes with respect to the curvature of the inner cylindrical wall;

[00036] FIG. 6 is a schematic sectional view of the cyclone combustion burner illustrating the cyclone effect of the combustion zone and the separation of suspended particles therein and its precipitation into the fuel bed;

[00037] FIG. 7 is a perspective view showing the construction of the support tray and the ash discharge augers;

[00038] FIG. 8 is an end view of the support tray showing the drive of the augers and its connection to a motor drive shaft;

[00039] FIG. 9 is a plan view illustrating the construction of the user interface pad;

[00040] FIG. 10 is a block diagram illustrating the construction of the controller and its associated component parts within a pellet burning stove constructed in accordance with the present invention;

[00041] FIG. 11 is a simplified schematic view wherein the cyclone combustion burner of the present invention is 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 absorbtive chilling devices, thermoelectric, thermophoto-

voltaic generators, and heat engines to provide thermal energy for their specific application;

[00042] FIG. 12 is another embodiment of the application as shown in Figure 11 but wherein the two cyclone gasifying combustion burners are separated from one another;

[00043] 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; and

[00044] FIG. 14 is a schematic illustration wherein the burner of the present invention is incorporated in a hot air or hydronic hot water producing furnace, herein provided with a solid fuel supply system.

DESCRIPTION OF PREFERRED EMBODIMENTS

[00045] Referring now to Figures 1 and 2, there is shown generally at 10 a solid fuel heating device having a combustion chamber 12 in which the cyclone gasifying combustion burner 11 of the present invention is incorporated to produce thermal energy. The cyclone combustion burner 11 is disposed at the bottom of a combustion chamber 12. 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 is provided with angularly oriented air jet holes as will be described later. 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. With domestic heating stoves as shown in Figures 1 and 2, air is drawn through the combustion burner 11 and the combustion chamber 12 as herein illustrated whereby to prevent the flow of combustion air and ash into the immediate area of stove when the door of the stove is open. However, it is conceivable

that with other applications of the present invention that air could be forced through the air jet holes by means of a blower connected to the manifold chamber 14 or conduits leading thereto from an intake air area.

[00046] As shown in Figure 2, heat exchange means in the form of hollow pipes 19 are disposed in 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 on the walls of the heating device but preferably spaced from the exhaust as indicated at 22 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.

[00047] The solid fuel heating device 10, as herein illustrated is a biomass pellet and grain-fed space heating stove and it comprises a hopper 23 in which are stored solid fuel pellets 24. The feed pellets are fed into the fuel bed 25 of the cyclone burner 11 by an auger 26 feeding a chute 27. The solid fuel, pellets 24 entering the cyclone burner 11 are projected into the fuel bed 25 by gravity and supported by a support means 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.

[00048] Referring now to Figures 3 to 6, there will be described the construction of the inner cylindrical wall 16 of the cyclone combustion burner 11. As hereinshown, the 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 within the combustion chamber. This cyclone is indicated by reference numeral 32 in Figure 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 we can orient the cyclone path to achieve optimum separation of suspended particles and sufficient retention time to burn the combustion gases. This reaction zone 33, defined by the inner cylindrical wall, is of a substantially predetermined length depending on the size of the cyclone combustion burner 11.

[00049] As shown in Figure 3, the air jet holes 31 are disposed in groups on at least two inclined axes 35, there being shown three groups of these holes in Figure 3 and this may vary depending on the diameter of the inner cylindrical wall. Each group of these air jet holes 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. It also causes suspended particles to gravitate to the fuel bed, as above-described. Therefore, although Figure 3 shows a preferred pattern for the angulated air jet holes, it is conceivable that other suitable patterns may produce a satisfactory result.

[00050] As shown in Figures 4 and 5, each of these air jet holes are disposed at a tangential angle 36, see Figure 5, with respect to the curvature of the inner cylindrical wall 16. They are also oriented at a transverse angle 37, see Figure 4, extending in the direction of the open top end 34. 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 these air jet holes at a low pressure wherein the air/fuel ratio is from about 6:1 to10:1 and this is sufficient to create a high velocity cyclone within the reaction zone 33.

[00051] The tangential angle 36 is in the range of between approximately 15° to 89° with respect to the curvature of the inner cylindrical wall. 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 Figure 5. Preferably, for a 4 inch diameter inner cylindrical housing, this angle is at approximately 61°. The transverse angle 37 is in the range of approximately 1° to 15° with respect to the transverse axis 40 as illustrated in Figure 4 and is preferably, as hereinshown, at an angle of 13°.

[00052] 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 causes 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. Particles at the center of the cyclone 32, herein illustrated by reference numeral 41', will also precipitate towards the fuel bed due to the fact that the center of the cyclone is an area of entrapment. These particles will 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.

[00053] As shown in Figures 3 and 4, other air jet holes, such as holes 45, are provided in the inner cylindrical housing whereby to admit combustion air into the fuel bed 25. These holes are not inclined 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 8:1 whereas with conventional pellet stoves, the fuel is burned at a fairly high ratio. 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 the burner of the present invention, it can be said that the system is an air-starved system and accordingly, the burner 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, it has been found that substantially no clinkers are formed.

[00054] It is pointed out that the inner diameter of the inner cylindrical wall 16 may vary within a minimum of 1

inch to 48 inches or more inches 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 2 inches to 48 inches or more. The air jet hole diameter may also vary from 1/16 of an inch to a maximum of 6 inches or more. The air jet holes 31 are also spaced apart at a predetermined distance from one another.

[00055] 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, these are automatically removed from the bottom of the fuel bed as will now be described with reference to Figures 6 to 8. As hereinshown the support tray 28 is an elongated shallow rectangular housing 50 in which there is disposed three auger screws 51 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 augers at a controlled speed rate. 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, we displace the ashes in the fuel bed thereby improving combustion of the solid fuel particles and simultaneously causing the ashes produced to percolate, to the bottom of the fuel bed area, and be displaced 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. The rate of speed of the motor 54 is very slow and determined by a controller 60 depending on various parameters.

[00056] Referring now to Figures 9 and 10, there will be described the operation of the controller 60. This controller 60 is connected to a user interface pad 61 that is provided with an internal memory 62 (see Figure 10), and which keypad permits a user to control the operation of the solid fuel biomass pellet heating device 10, such as illustrated in Figures 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 Figures 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 is 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 these 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 are also 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.

[00057] As shown in Figure 10, the 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 is also conveniently located on the outside, back wall of the combustion chamber 12 and senses the temperature thereof. 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.

[00058] As also shown in Figure 10, the controller controls the speed of the combustion fan 68, see Figure 1. It also controls the speed of the convection fan 21 that is used to force the air through the heat exchangers 19. As mentioned hereinabove, it also controls 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.

[00059] 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.

[00060] 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 low temperature sensor disk 65 detects if there is no longer a fire in the burner and the controller will turn the heating device off once the unit has cooled down to a pre-set temperature.

[00061] 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 would be provided to allow oxygen to catalyze with the volatile gases which are entering the burner from the gasification chamber.

[00062] 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 volatized 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.

[00063] As shown in Figure 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. 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, but the one shown herein is simple to construct and effective.

[00064] 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

[00065] 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, $CO_2$, $NO_x$) were taken at a rate of 1 $ft^3$/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

- Negligible amount of solid particulates were found in the exhaust gas.
- Less than detectable amount of VOCs were found.
- $NO_x$ concentrations were below acceptable emission standards.
- In most cases CO concentration was within a range of 11-25 ppm/hr.
- Exhaust temperature changed between 130 and 150°C.

- Corn yielded lowest CO emissions
- The following hierarchy of the biomass fuel was established at lower feeding rate of 2.5 lbs/hr: bark>wood>corn.
- The following hierarchy of the biomass fuel was established at a higher feeding rate of 3.0 lbs/hr: corn>bark>wood.

**[00066]** It can therefore be concluded that with the construction of a cyclone burner having air jet holes oriented to create a cyclone 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 ($No_x$), is substantially reduced below acceptable regulated levels.

**[00067]** Referring now to Figure 11, there is shown a modification of the cyclone gasifying combustion burner of the present invention 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 Figure 11, the burner 11 of the present invention is 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. 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.

[00068] 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 hereinshown 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 Figures 7 and 8 would be connected to the bottom end of the vertical combustion burner 15.

[00069] As hereinshown, 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 is 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.

[00070] Figure 12 shows an embodiment similar to Figure 11 but wherein the combustion burner housing 11' is not directly coupled to the vertical combustion burner housing 11. As hereinshown, 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 hereinshown. 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.

[00071] As previously described, it is the disposition of the air jet holes within the inner cylindrical wall that creates a cyclone 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, Figure 13 shows an 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 hereinshown 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.

[00072] 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.

[00073] Referring now to Figure 14, there is shown a further embodiment wherein the high efficiency cyclone gasifying combustion burner of the present invention is incorporated into a hot air furnace 120. 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 Figure 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.

[00074] As described above, the high efficiency cyclone gasifying combustion burner of the present invention 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 as a thermal heat source for a heat engine which also forms part of the present invention.

**[00075]** It is within the ambit of the present invention to cover any obvious modifications of the preferred embodiment described herein, provided such modifications fall within the scope of the appended claims.

CLAIMS

1. A cyclone gasifying combustion burner comprising a combustion housing defined by an inner cylindrical wall surrounded by a manifold chamber configured with a combustion air inlet, said inner cylindrical wall having air jet holes therein of substantially predetermined diameter 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 drawn in said reaction zone and to cause suspended particles to gravitate into said fuel bed and thereby substantially reducing the emission of pollutants into the atmosphere, said air jet holes being disposed spaced apart at substantially predetermined distances and in series on substantially predetermined inclined axes to create a unidirectional combustion air cyclone flow in said reaction zone, said predetermined angle of said air jet holes is defined by a first tangential angle with respect to a transverse axis to the curvature of said inner cylindrical wall, and a second transverse angle with respect to said transverse axis of said inner cylindrical wall and angulated in the direction of an open end of said inner cylindrical wall, said suspended particles being 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, said

reaction zone having a length sufficient to provide said substantially complete combustion of said combustion gases and the containment of said particles to substantially eliminate said emission of pollutants.

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 tangential angle is in the range of between approximately 15° to 89° with respect to said transverse axis to the curvature of said cylindrical wall.

4. A cyclone gasifying combustion burner as claimed in claim 1 wherein said tangential angle is at approximately 60 degrees.

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

6. A cyclone gasifying combustion burner as claimed in claim 5 wherein said transverse angle is approximately 13 degrees.

7. 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.

8. 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.

9. 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.

10. 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

11. 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.

12. A cyclone gasifying combustion burner as claimed in claim 11 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 pyrolyisis gasification combustion zone.

13. 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.

14. A cyclone gasifying combustion burner as claimed in claim 13 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.

15. A cyclone gasifying combustion burner as claimed in claim 14 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.

16. A cyclone gasifying combustion burner as claimed in claim 1 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.

17. A cyclone gasifying combustion burner as claimed in claim 1 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.

18. A cyclone gasifying combustion burner as claimed in claim 17 wherein said heating device is a hot air furnace.

19. A cyclone gasifying combustion burner as claimed in claim 17 wherein said solid fuel is coal.

20. A cyclone gasifying combustion burner as claimed in claim 17 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.

21. A cyclone gasifying combustion burner as claimed in claim 20 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 pyrolyisis combustion bed, and an exhaust device to exhaust gases from said combustion chamber to atmosphere.

22. A cyclone gasifying combustion burner as claimed in claim 21 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.

23. A cyclone gasifying combustion burner as claimed in claim 21 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.

24. 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.

25. 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.

26. 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.

27. A cyclone gasifying combustion burner as claimed in claim 26 wherein there is further provided an

igniter in said inner cylindrical wall of said further combustion housing.

28. A cyclone gasifying combustion burner as claimed in claim 26 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.

29. A cyclone gasifying combustion burner as claimed in claim 26 wherein each said manifold chamber is connected to a combustion air pressure generating device.

30. A cyclone gasifying combustion burner as claimed in claim 29 wherein said air pressure generating device is a fan.

31. A cyclone gasifying combustion burner as claimed in claim 29 wherein each said manifold chamber is interconnected together.

32. 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.

33. A cyclone gasifying combustion burner as claimed in claim 32 wherein there is further provided an igniter in said inner cylindrical wall of said further combustion housing.

34. A cyclone gasifying combustion burner as claimed in claim 32 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.

35. A cyclone gasifying combustion burner as claimed in claim 32 wherein each said manifold chamber is connected to a combustion air pressure generating device.

36. A cyclone gasifying combustion burner as claimed in claim 35 wherein said air pressure generating device is a fan.

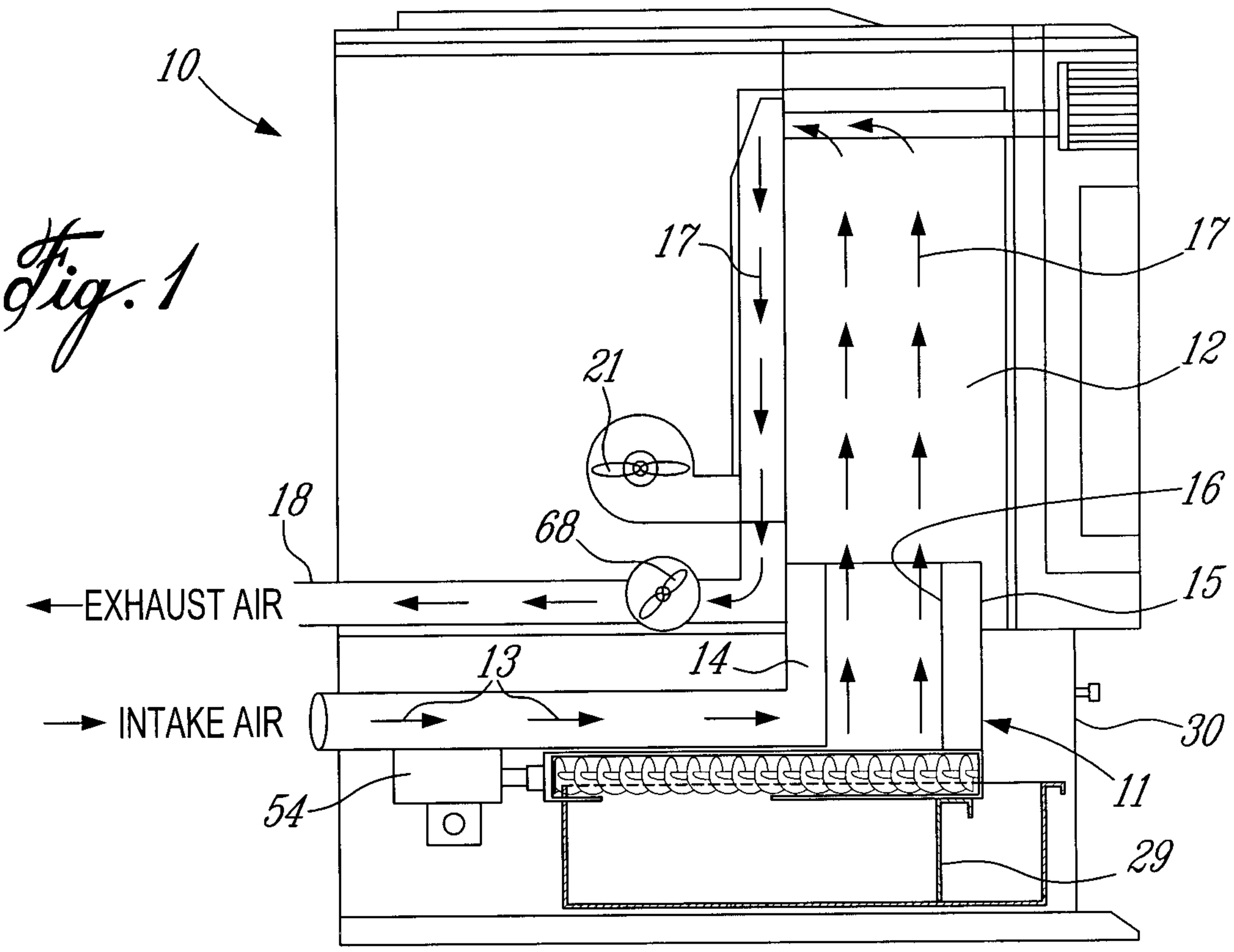

10
17
17
12
21
16
18
68
15
EXHAUST AIR
14
13
INTAKE AIR
30
11
54
29

Fig. 1

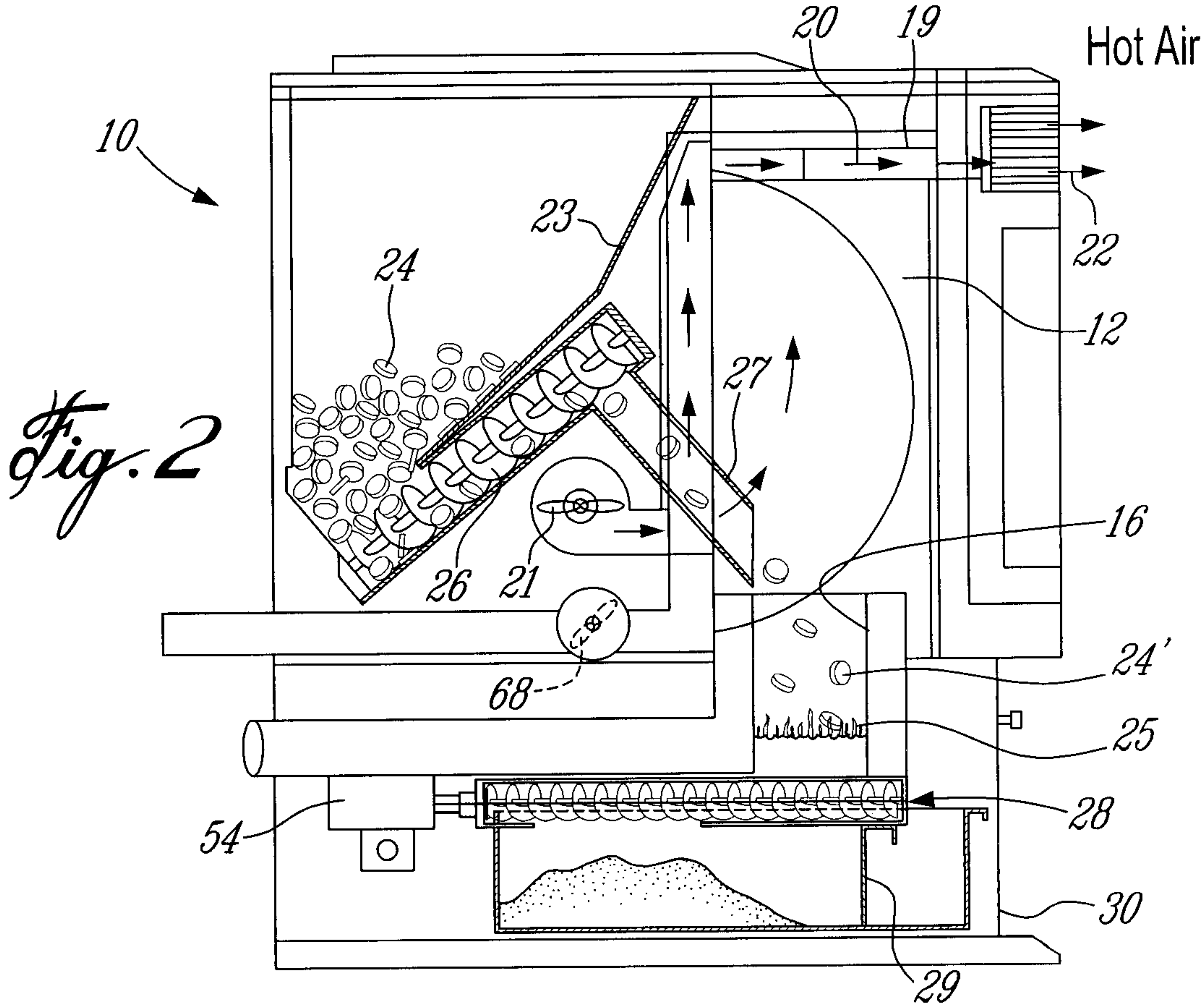

Hot Air
20
19
10
23
22
24
12
27
16
26
21
68
24'
25
28
54
30
29

Fig. 2

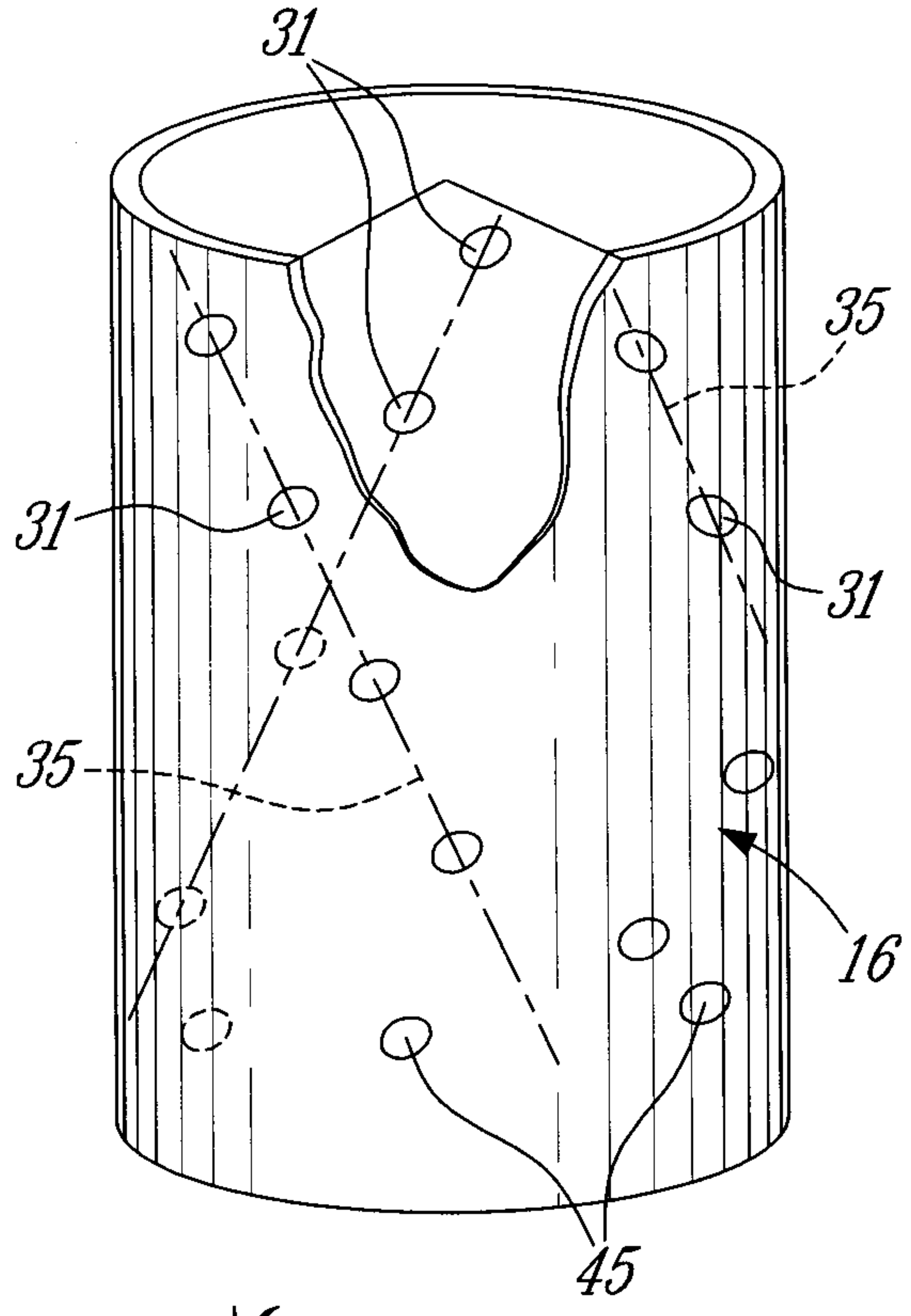



Fig. 3

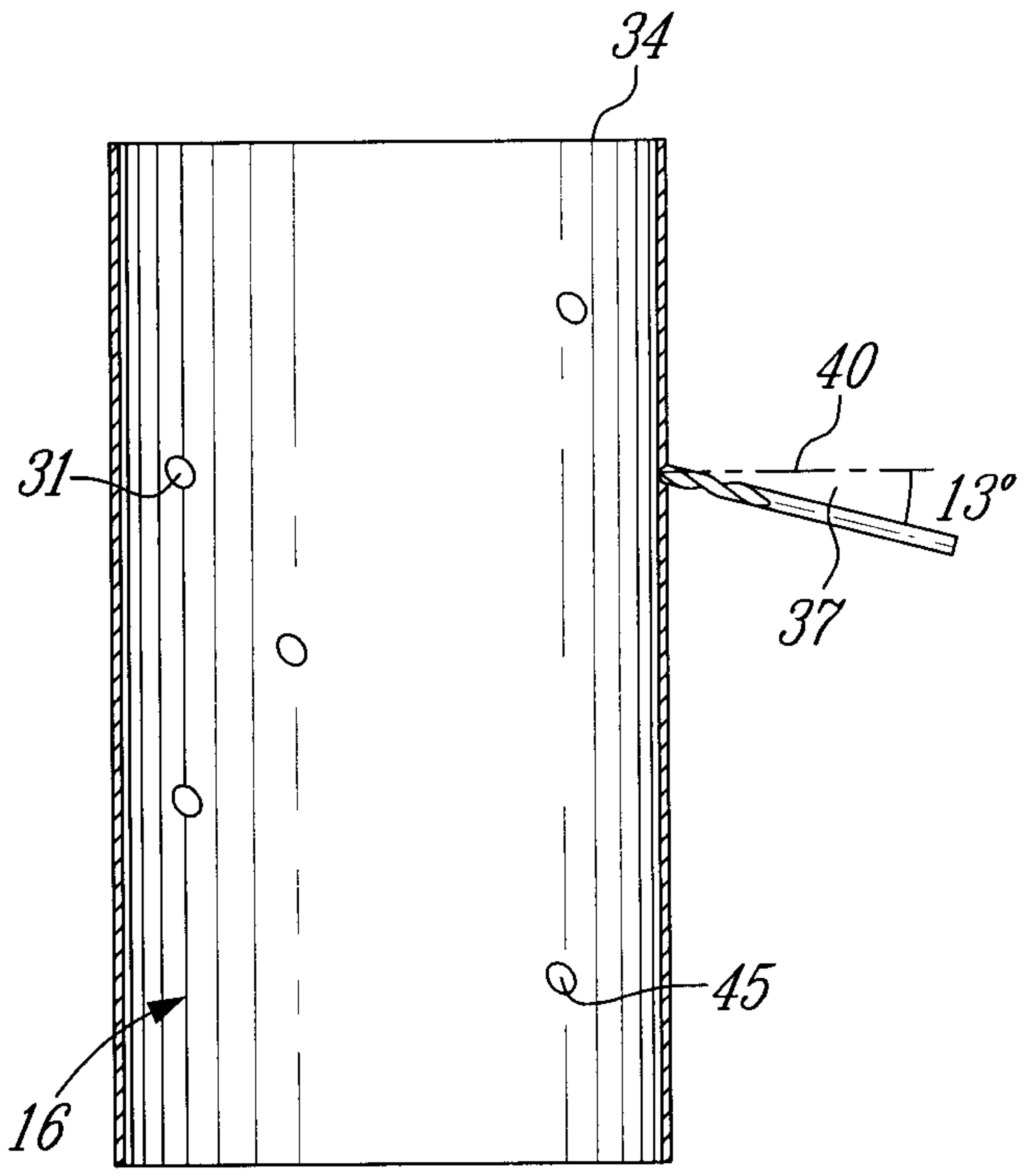



Fig. 4

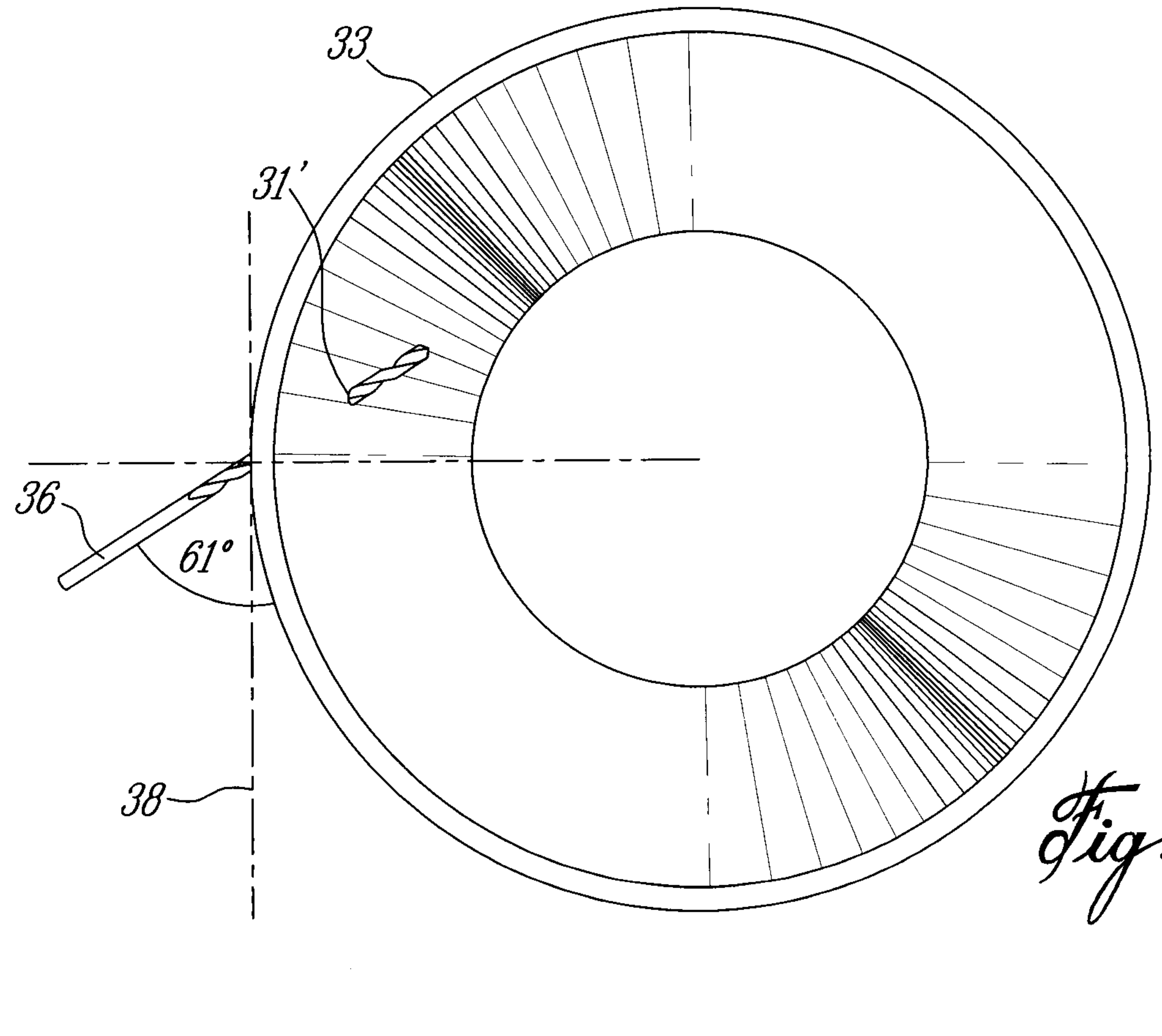



Fig. 5

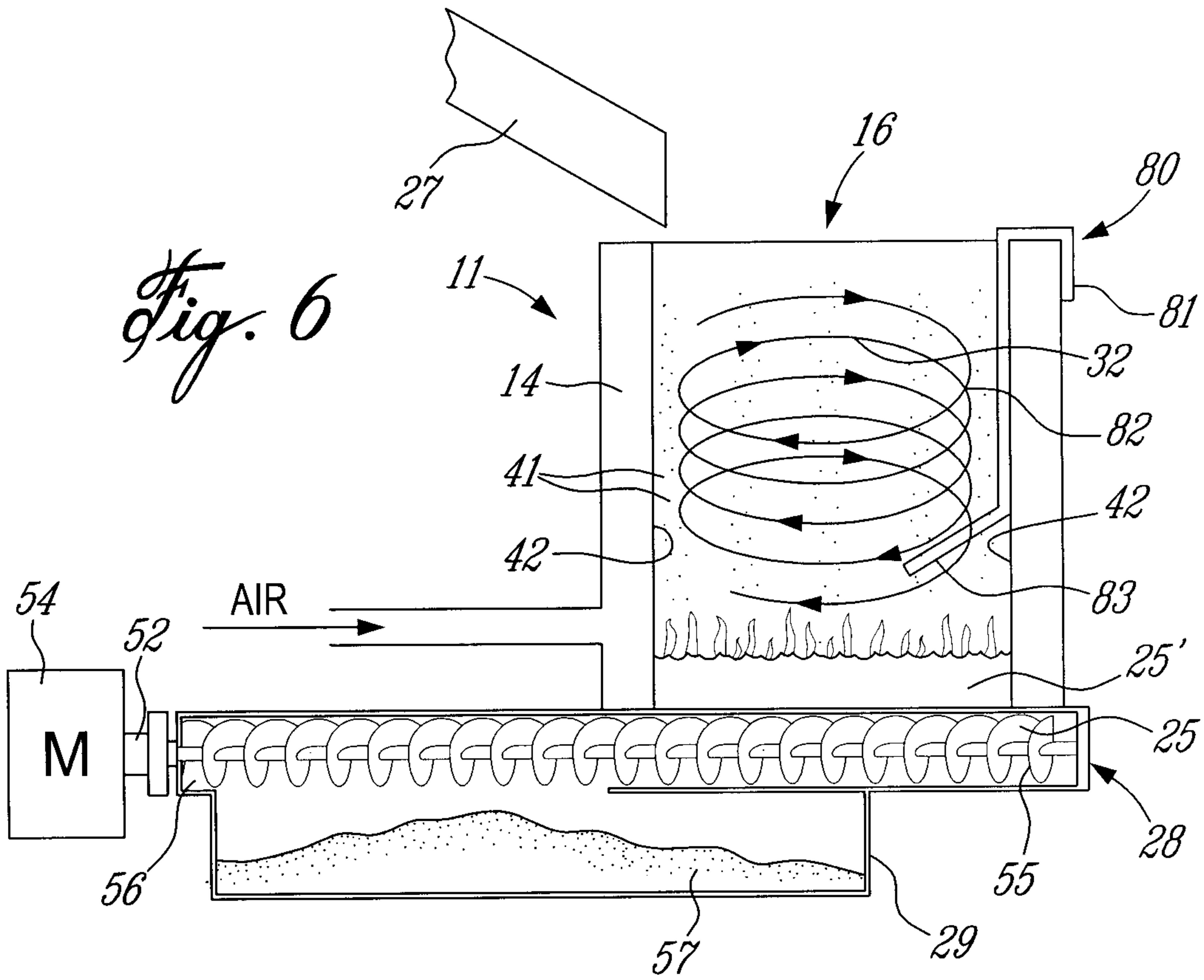



Fig. 6

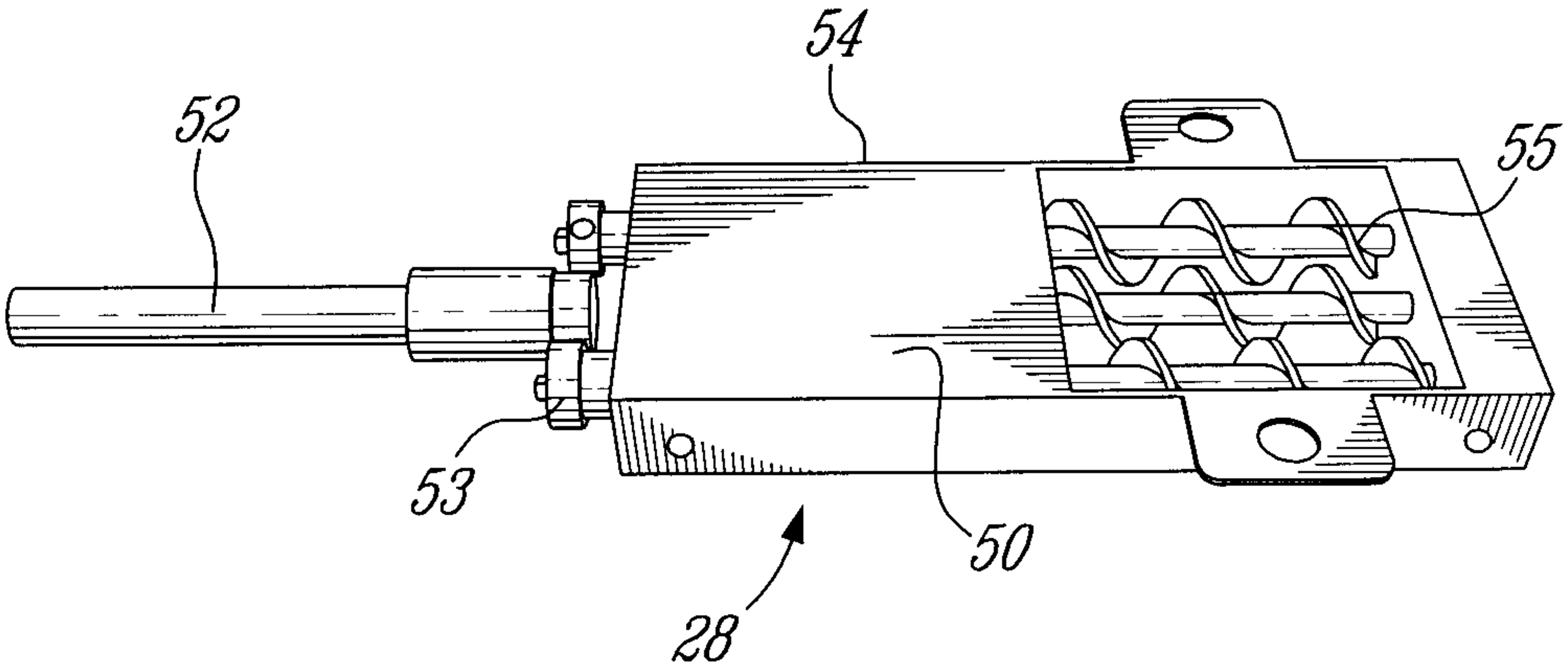



Fig. 7

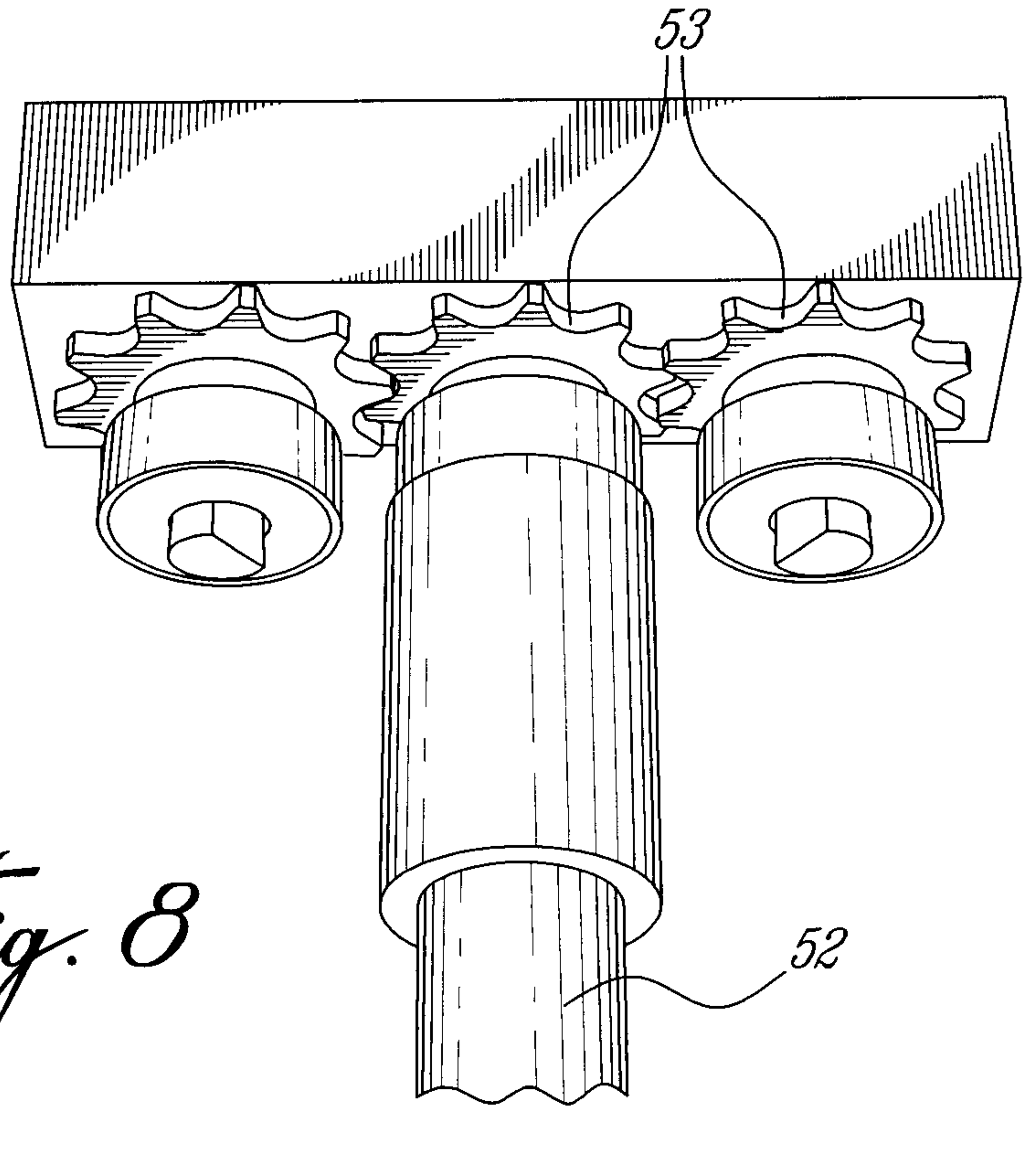



Fig. 8

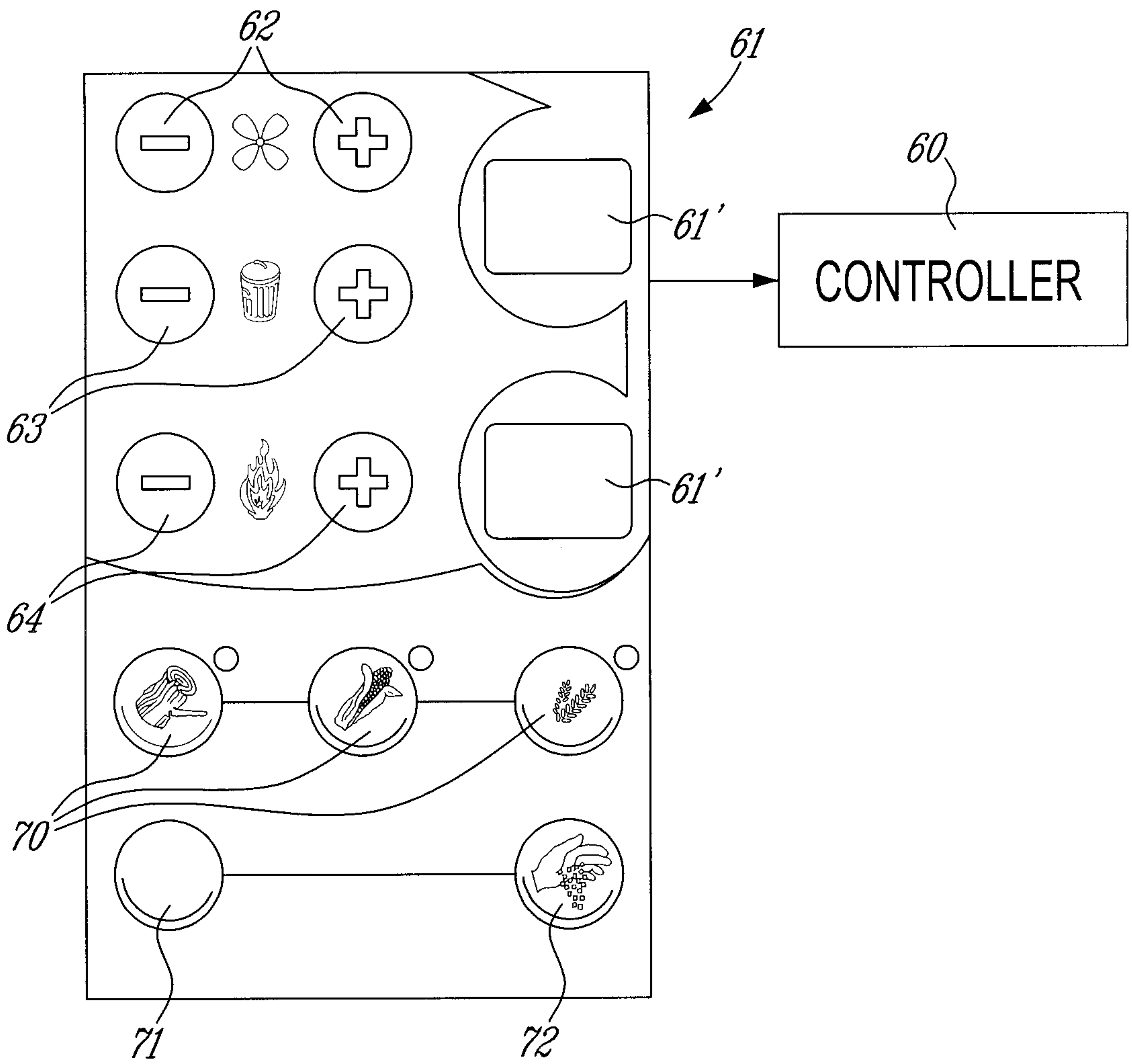



Fig. 9

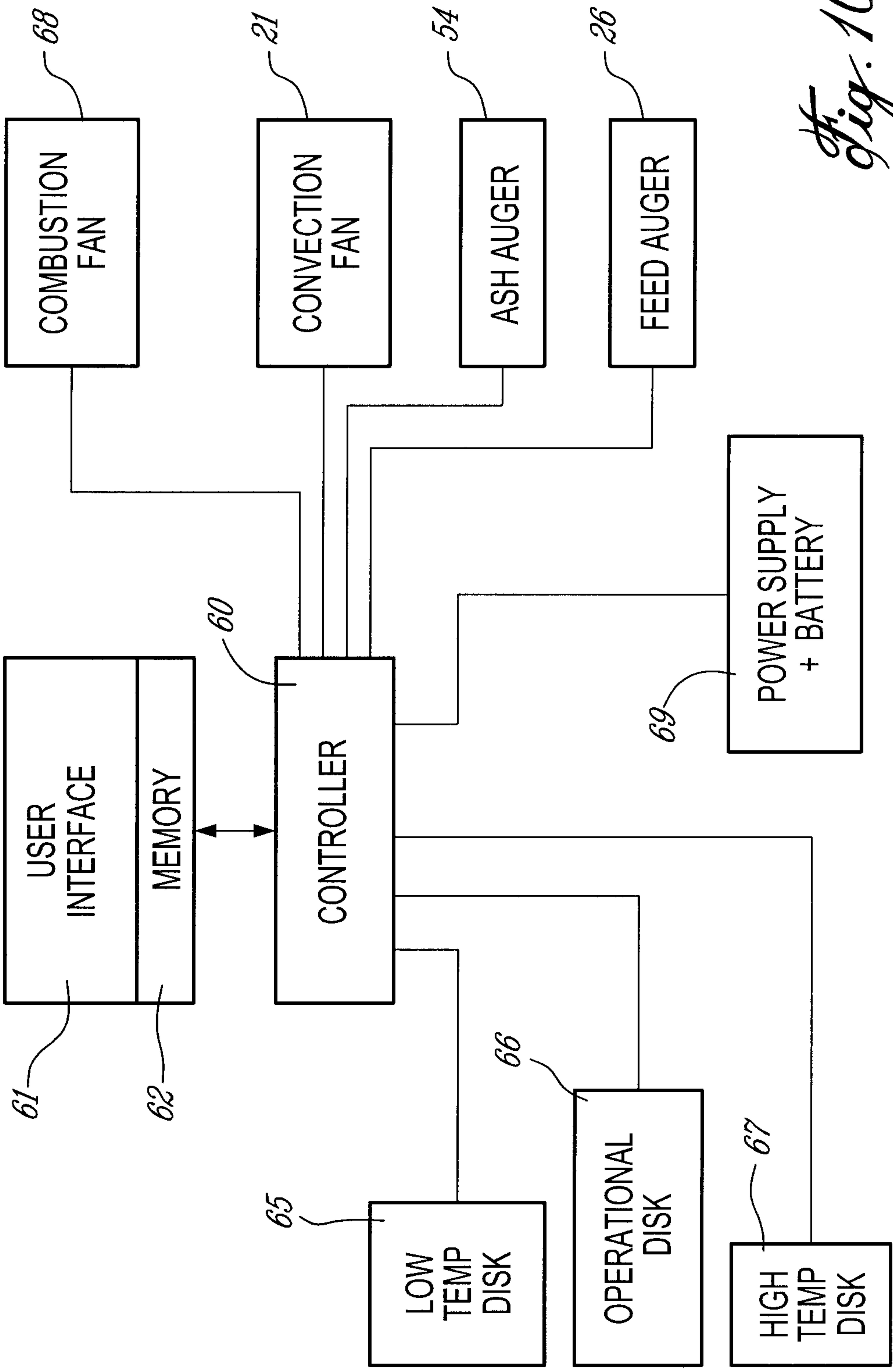

COMBUSTION FAN
68
CONVECTION FAN
21
ASH AUGER
54
FEED AUGER
26
POWER SUPPLY + BATTERY
69
60
CONTROLLER
USER INTERFACE
61
MEMORY
62
LOW TEMP DISK
65
OPERATIONAL DISK
66
HIGH TEMP DISK
67

Fig. 10

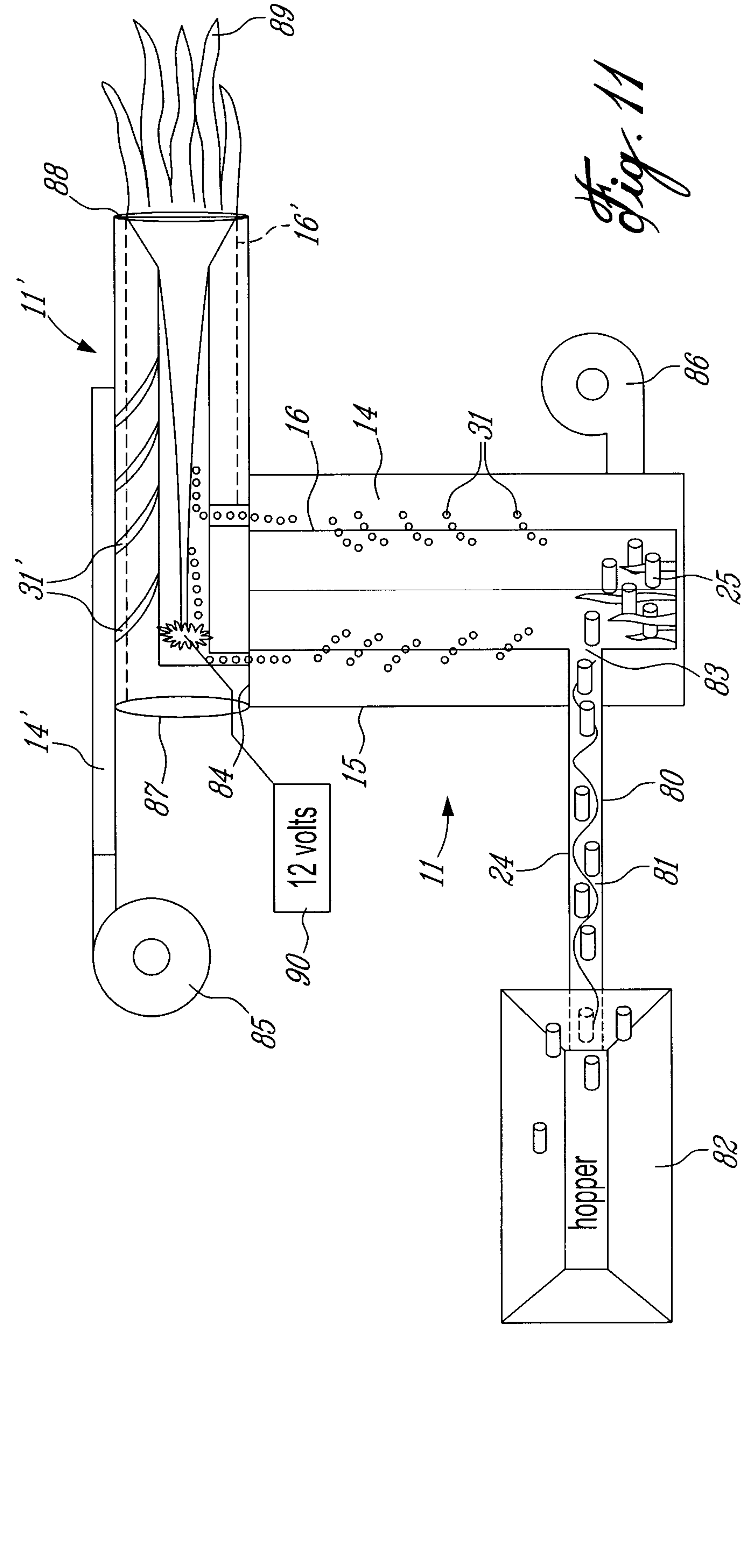

89
88
16'
11'
16
14
31
86
31'
25
83
14'
87
84
15
12 volts
90
11
24
80
81
85
hopper
82

Fig. 11

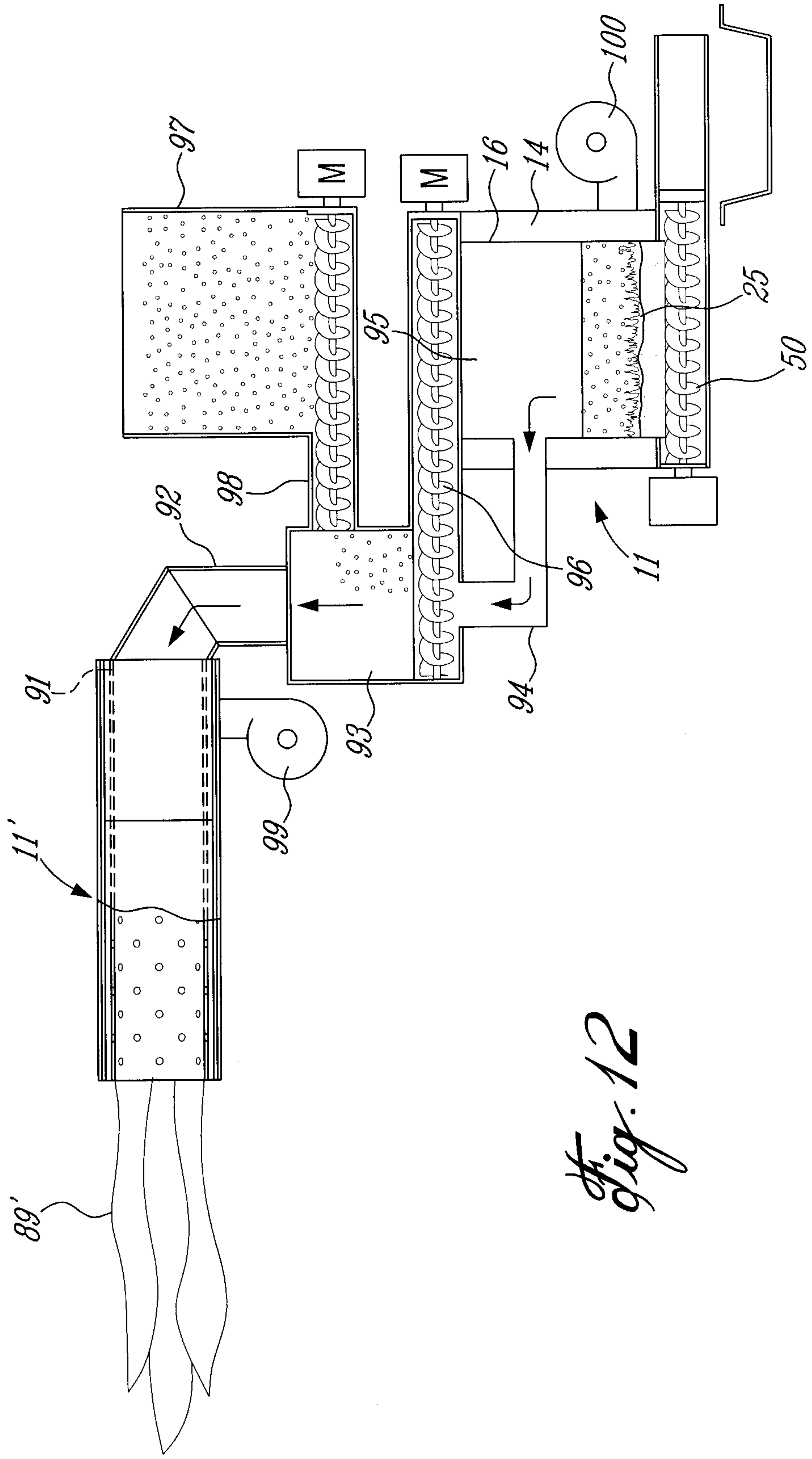



Fig. 12

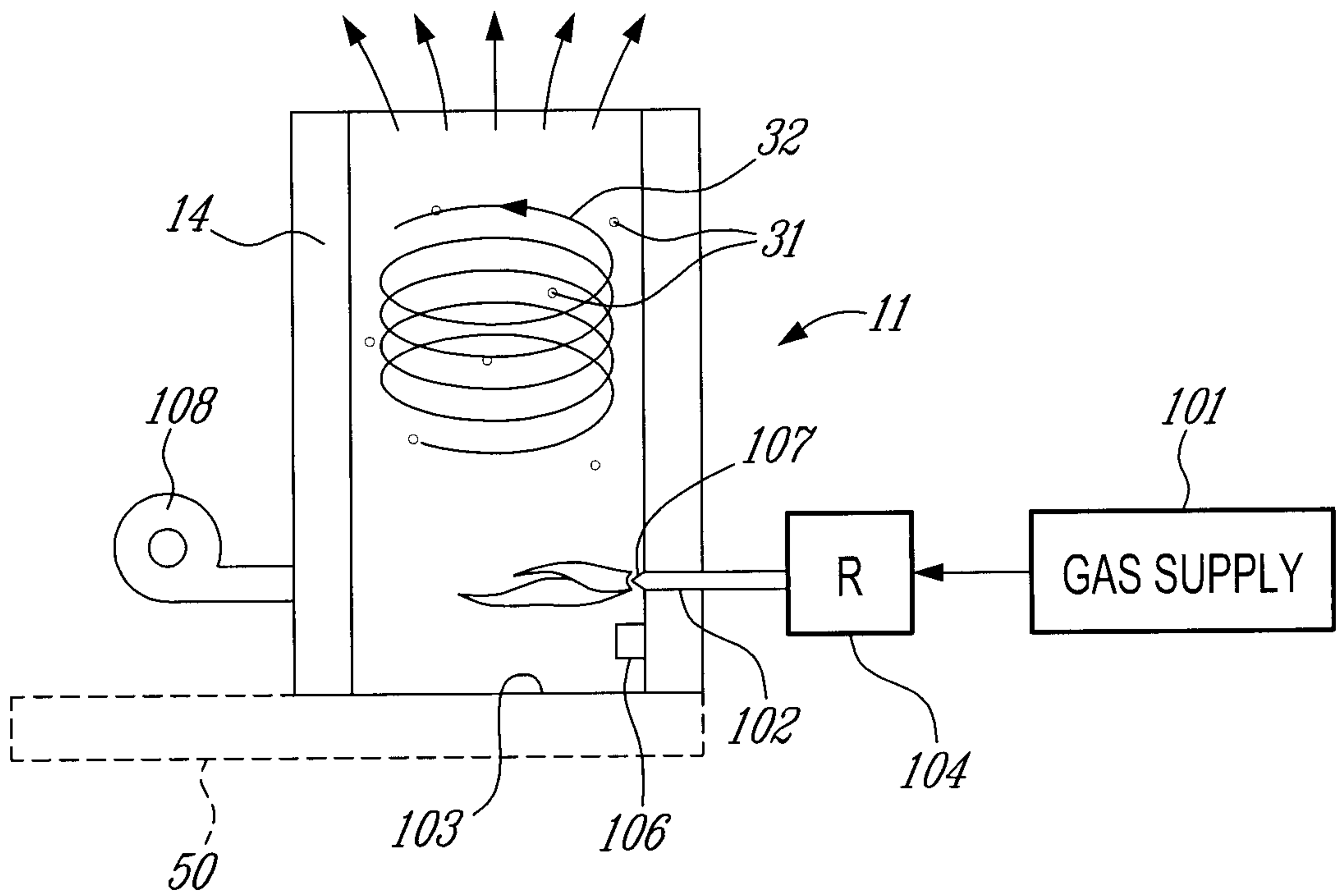

32
14
31
11
108
101
107
R
GAS SUPPLY
102
104
103
106
50

Fig. 13

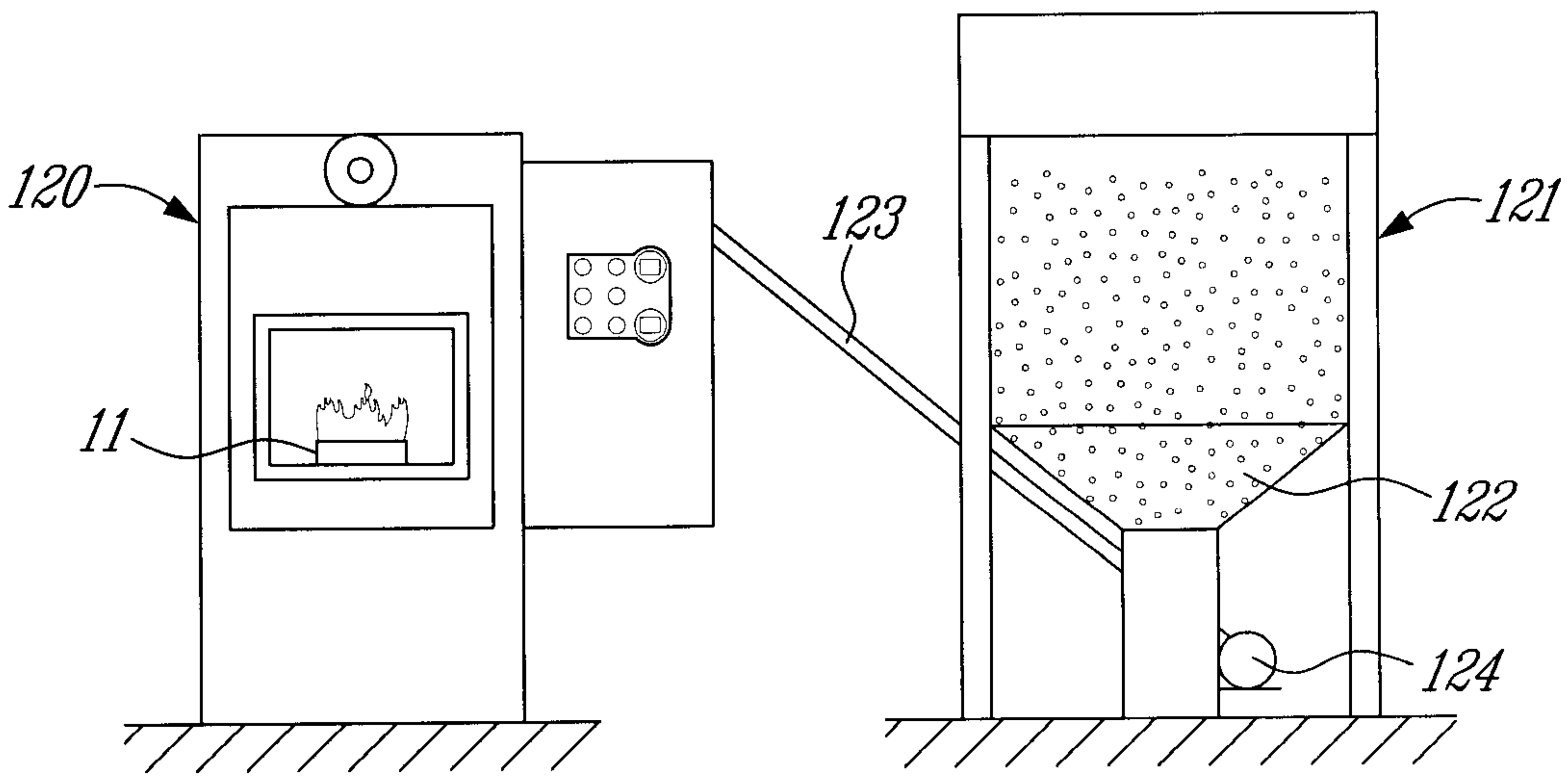
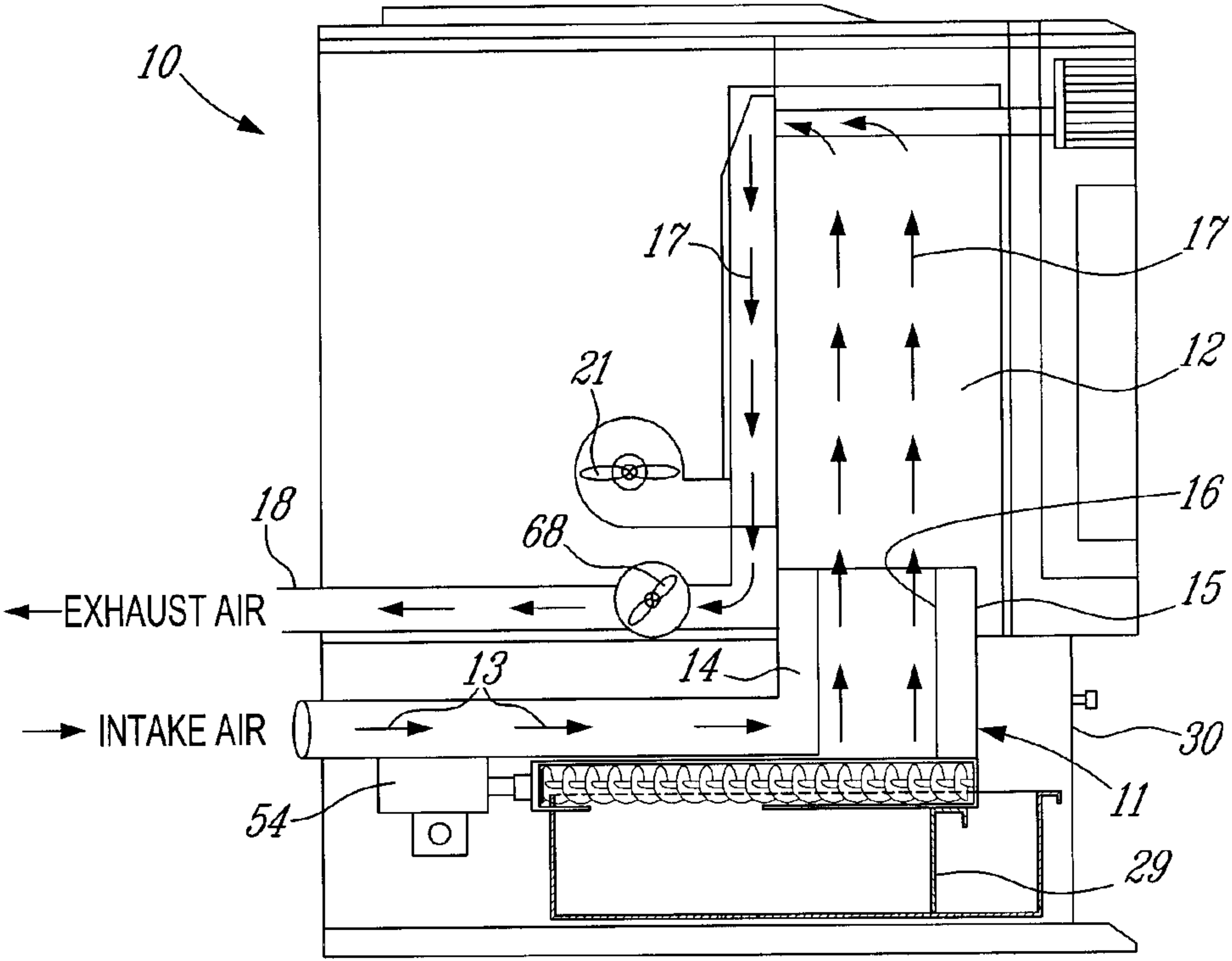

120
123
121
11
122
124

Fig. 14


10
17
17
12
21
16
18
68
15
EXHAUST AIR
13
14
INTAKE AIR
30
11
54
29