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(54) **SOLID FUEL STOVE WITH IMPROVED COMBUSTION**

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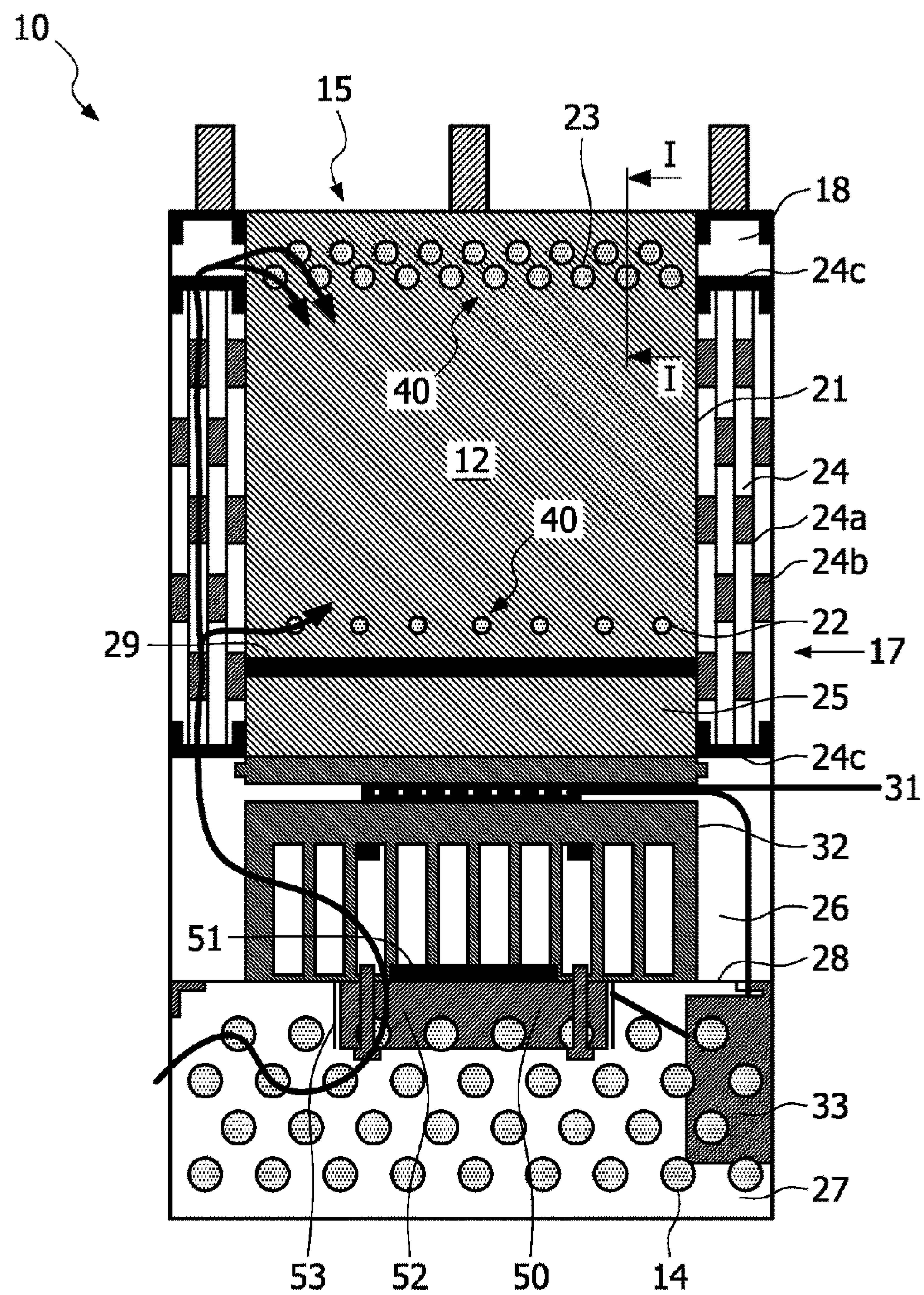
(57) **ABSTRACT**

The invention relates to a solid fuel stove comprising a combustion chamber (**12**) for containing combustion fuel and a blower assembly (**50**) configured to provide airflow entering the combustion chamber in operating condition. When guiding means (**40**) establish airflow entering the combustion chamber substantially in a downwardly direction the combustion process of the stove is very clean and efficient.



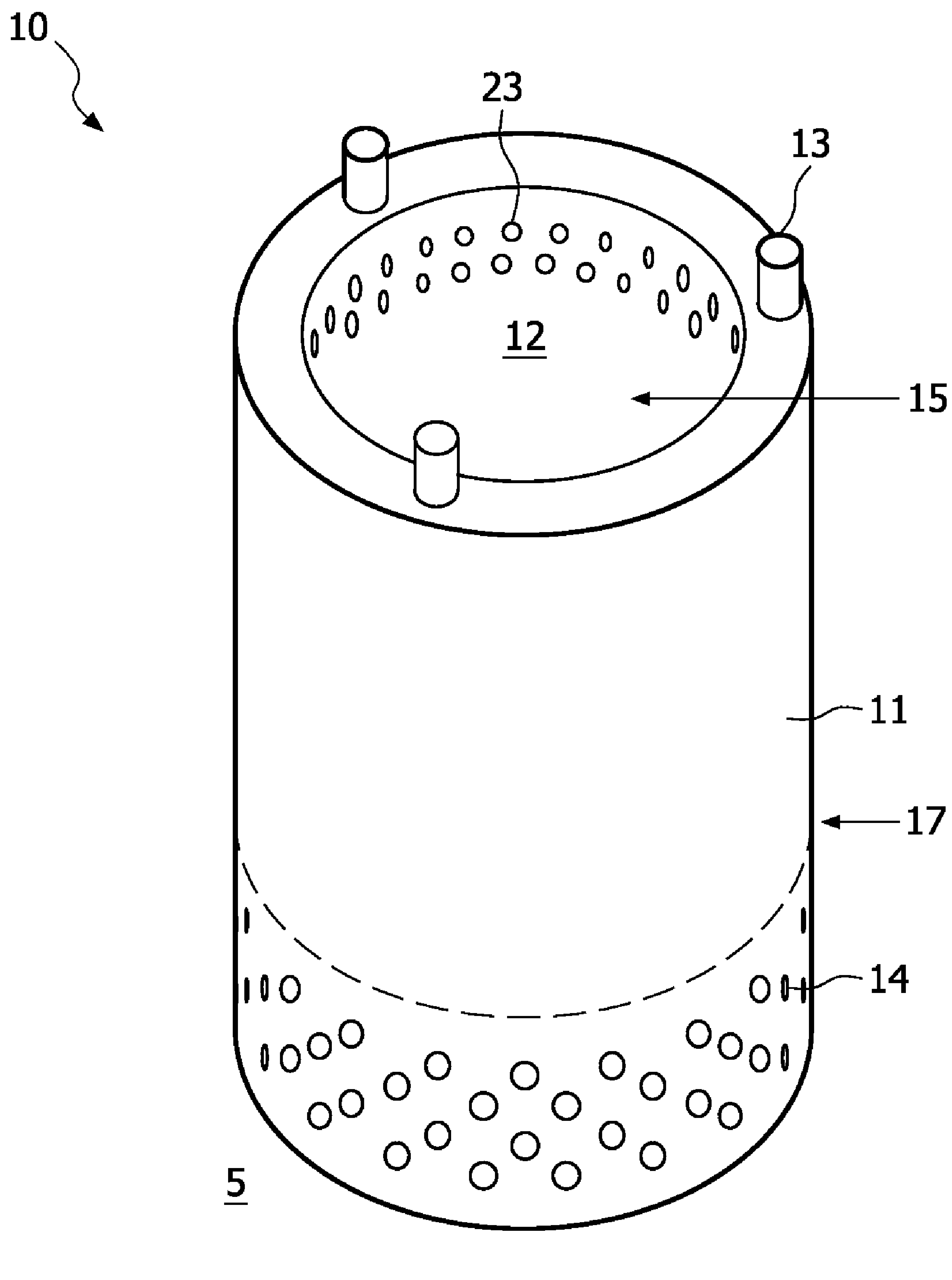


FIG. 1

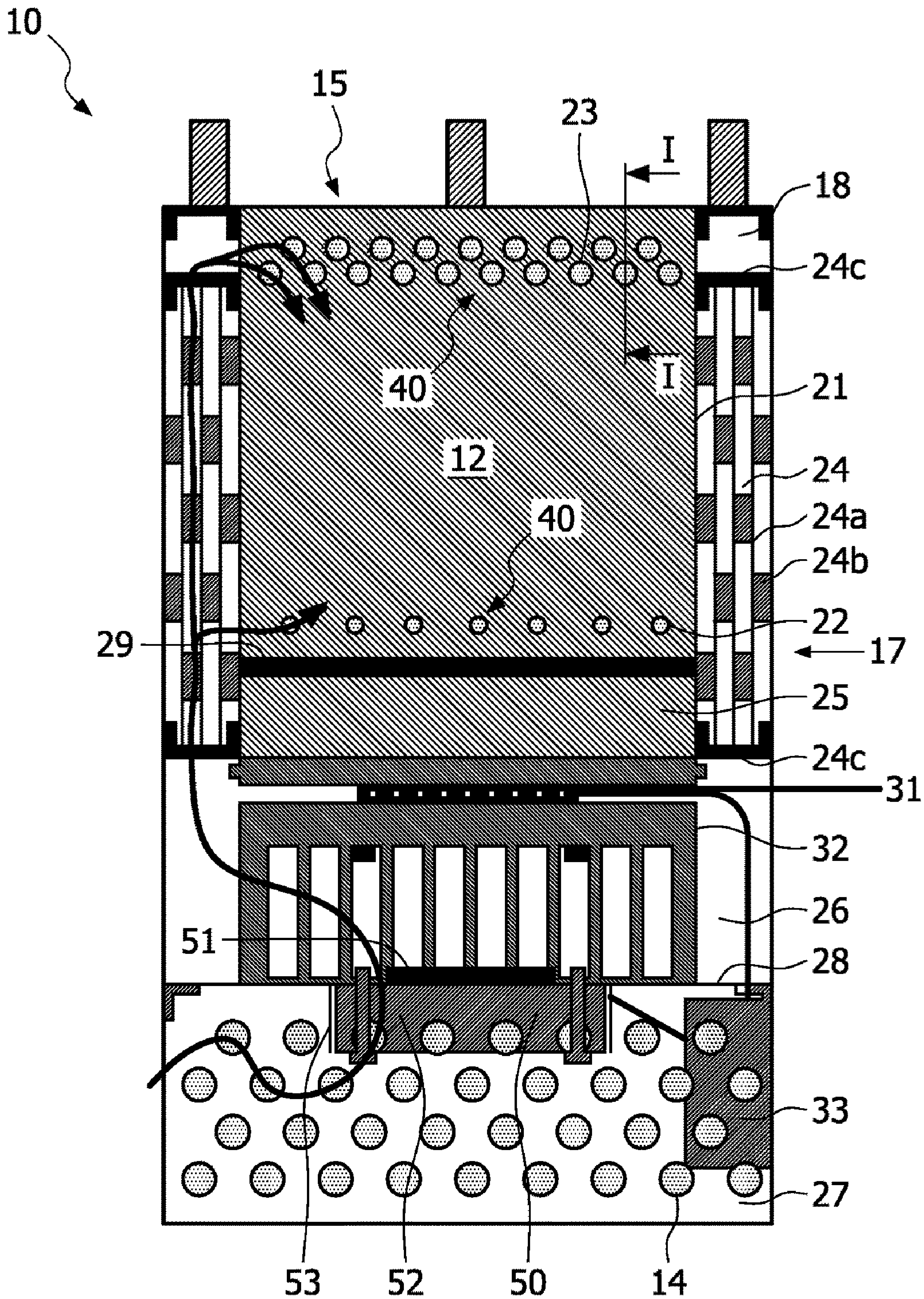

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FIG. 2

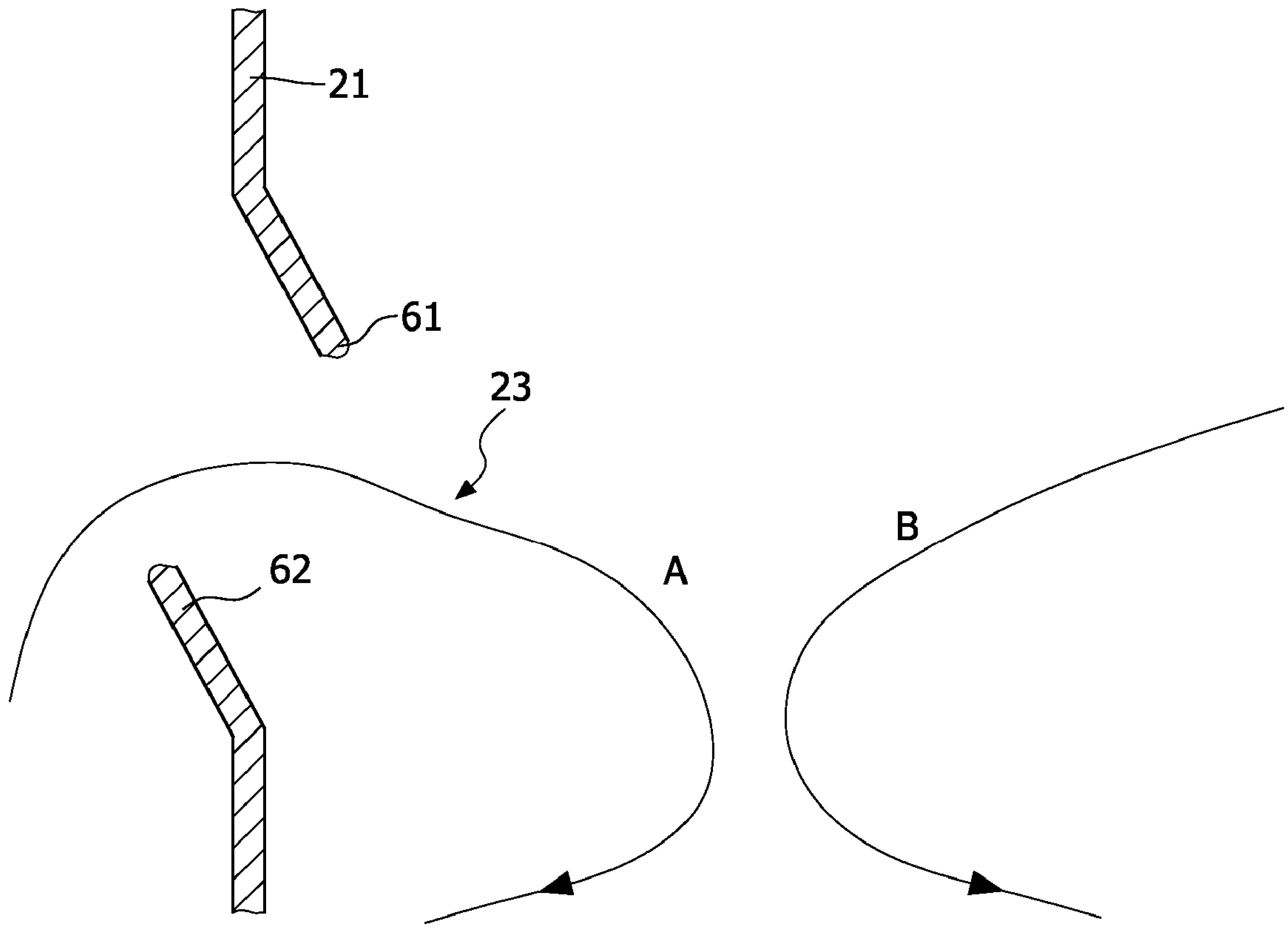

FIG. 3

SOLID FUEL STOVE WITH IMPROVED COMBUSTION

[0001] The present invention relates to cooking stoves with improved combustion. In particular the present invention relates to cooking stoves capable of burning solid fuels, such as wood, using forced air circulation in the combustion chamber.

[0002] It is estimated that approximately 2.5 billion people in the world burn wood for cooking. The known stoves and processes are typically inefficient and have incomplete combustion, which results in substantial smoke emissions and contributes to the global warming process. Many deaths each year may be attributed to such polluted smoke emissions. In addition, poor efficiency woodstoves use more natural timber resource with consequences for deforestation.

[0003] In domestic combustion of wood, air pollution occurs because of incomplete combustion of the volatiles released from the wood. Volatile organic compounds are released from wood at temperatures as low as room temperature, but substantial, rapid release only begins when exothermic reactions commence (250° C.). The volatiles form a complex mix of combustible gases. The ignition temperature of the combustible gas mix is approximately 600° C. Many of the unburned volatiles released from wood will condense to form fine particles when cooled to near-ambient temperatures. This is what we observe as wood-smoke. Incomplete combustion of the volatiles occurs for several reasons. When a batch of wood is added, the heat from the coals and appliance soon causes gases to be released from the wood. When lighting a fire, the burning paper and kindling provide this heat. If the volatiles are not exposed to a high temperature source (flame or glowing charcoal) they will not ignite and simply pass up the flue/chimney causing pollution. If the gas does ignite, it can be quenched if it is cooled by a cold surface (e.g. the metal walls of a cool firebox) or cool combustion air. If the combustible gas is not well mixed with air (oxygen) it will not burn. If combustion air is reduced to slow the combustion rate, there may be insufficient oxygen for complete combustion.

[0004] GB 2125160 describes a cooking stove having a combustion air chamber into which air for combustion is drawn from the exterior of the stove either by natural convection or by a hand-operated air pump or combination of both. The air enters the combustion chambers through one or more apertures in the bottom of the chamber.

[0005] It is an object of the present invention to provide a solid fuel stove that allows a clean combustion process.

[0006] According to the present invention a solid fuel woodstove is provided comprising;

[0007] a combustion chamber for containing combustion fuel, which chamber has a lower side portion for accommodating fuel and an upper side portion;

[0008] a blower assembly configured to provide airflow entering the combustion chamber in operating condition;

[0009] guiding means to direct the airflow into the combustion chamber;

[0010] wherein the guiding means direct the airflow from the upper side portion to the lower side portion.

[0011] The stove according to the present invention has proven to give a very clean combustion process. A cleaner combustion process reduces both the emission of harmful combustion gasses, such as carbon monoxide (CO) and condensed volatile organic compounds. The specific airflow as created by the guiding means allows the combustible gasses in the hot combustion chamber to combust completely before eventually exiting the combustion chamber and thus improves the cleanliness of the combustion process. When a transverse or an upward airflow is established in the combustion chamber there is a risk of combustibles gasses being entailed by such airflow outside the chamber before the combustible gasses are burned completely. This is especially the case when such gasses reach a higher part of the combustion chamber where the temperature is relatively low. The airflow according to the invention generates some kind of turbulent air mixture, which apparently is very advantageous with relation to a complete combustion. There is more time for the combustible gases in the combustion chamber to completely burn before eventually exiting the combustion chamber. As it is generally known complete combustion means a clean combustion. Detailed measurements with stoves according to the present invention indicate reduced levels of residual smoke and volatile organic matter. An additional advantage is that flames will not longer touch a cooking vessel disposed on the stove allowing a significant reduction of soot levels on the cooking vessels. The guiding means can have a relatively simple construction, which does not complicate the design of the stove. Of course apart from the blower assembly there are other sources of air can enter the combustion chamber, such as air entering through an (partially) open upper side portion or through openings in the lower side portion by natural convection. If the airflow in the combustion is substantially directed from the upper side portion to the lower side portion the combustion process will be very clean, as was indicated by several experiments.

[0012] According to a preferred embodiment the guiding means comprise a plurality of apertures provided in a wall of the combustion chamber at the upper side portion. By providing apertures a simple yet effective guiding means can be obtained. It is especially preferred if the upper edge of an aperture is inclined inwardly with relation to the combustion chamber and a lower edge of an aperture is inclined outwardly with relation to the combustion chamber. This construction is advantageous with relation to manufacturability in case of a relatively thin wall, because it is easier to deform the wall around the apertures. In another preferred embodiment the apertures comprise drilling holes having an inclined pitch with relation to the wall. Such apertures are easier to manufacture in case of a relatively thick wall.

[0013] Furthermore it is preferred if the apertures are substantially evenly distributed along the contour of the combustion chamber. This has the advantage that opposing streams of air will meet somewhere in the centre of the combustion chamber, which results in a turbulent mixture of air while improving the combustion process.

[0014] It is also advantageous if each aperture is disposed at a distance from the upper side portion. This has the advantage that the flames will not directly contact cooking utensils placed on top of the stove, thereby preventing the formation of soot at such utensils.

[0015] According to another preferred embodiment the guiding means establish airflow at the lower side portion of the combustion chamber. The guiding means to this end preferably comprises a plurality of apertures at the lower side portion of the combustion chamber. Experiments have proven that addition of airflow at the lower side portion of the combustion chamber will assist the gasification of components that are usually hard to gasify, such as charcoal. This will benefit the combustion process.

[0016] It is preferred when a preheat chamber is disposed around the combustion chamber, which preheat chamber provides air flow communication from the blower assembly into the combustion chamber and comprises an air distributor including heat reflectors adapted to reflect heat radiated from the combustion chamber back towards the combustion chamber. The air distributor guides the airflow and reflects heat back into the combustion chamber. Air entering the combustion chamber is preheated, while an outer surface remains sufficiently cool in operation to be safe to the touch.

[0017] In a preferred embodiment a rechargeable electrical power source for driving the blower assembly and a thermoelectric element are provided, wherein the thermoelectric element is configured to provide power to the blower assembly and to the rechargeable power source. This gives more freedom with relation to the (electric) power supply for driving the blower assembly and makes the woodstove independent from connection to the main power grid or to an external battery. Moreover it is very advantageous with respect to the overall energy consumption, especially in view of the fact that the wood stoves according to the invention typically are powered by a rechargeable energy source, such as a start-up battery. A woodstove provided with a thermoelectric element is described in detail in the non-pre-published application IB2006/050920, which is incorporated herein by reference.

[0018] It should be acknowledged that the embodiments described above, or aspects thereof, may be combined.

[0019] Embodiments of the present invention will now be described by way of example and with reference to the accompanying drawings in which:

[0020] FIG. **1** shows a perspective view of a solid fuel stove suitable for cooking;

[0021] FIG. **2** is a cross section view schematically showing internal detail of the stove of FIG. **1**;

[0022] FIG. **3** shows a schematic side cross sectional view according to line I-I in FIG. **2**.

[0023] With reference to FIG. **1**, a solid fuel stove **10** comprises a substantially cylindrical housing **11**, a combustion chamber **12** formed within an upper portion of the housing and having a generally open upper side portion **15** for use as a cooking surface. The generally open upper side portion **15** includes a number of support struts **13** or the like for supporting cooking utensils such as a pan on the top. The generally open upper side portion **15** may be at least partially covered by a mesh, grid or other open structure (not shown) for further supporting a cooking vessel while still allowing efficient egress of heat in an upward direction. The stove **10** preferably is placed on a flat and stable surface **5**.

[0024] Opposite to the open upper side portion **15** a lower side portion **17** (shown in dotted line in FIG. **1**) of the combustion chamber **12** provides accommodation for the solid fuel. The fuel typically is thrown into the combustion chamber **12** through the open upper side portion **15** by hand whenever fresh supply of fuel is needed. It should be noted that the terms ‘upper side portion’ and ‘lower side portion’ here are only used to be able to distinguish between the typical parts of the combustion chamber as it is positioned in its normal upright operating position as shown in FIG. **1**.

[0025] The housing **11** includes a series of air inlets **14** at a lower end thereof for ingress of air, which is used for forced air convection through the combustion chamber **12** as will be described below. The stove **10** preferably is a portable stove and therefore may be provided with a removable carrying handle (not shown) which may be attached to brackets on the housing **11** (also not shown). A series of upper apertures **23** of the combustion chamber **12** are also visible in FIG. **1**.

[0026] FIG. **2** shows the internal arrangements of a preferred embodiment of the stove **10**. An inner cylindrical wall **21** defines the combustion chamber **12**. Guiding means **40** of the combustion chamber **12** comprises a series of lower apertures or air outlets **22** and a series of upper apertures or air outlets **23**. The upper apertures are shaped such that air flowing into the combustion chamber is directed from the open upper side portion to the lower side portion or downwardly with relation to the support surface **5**. The apertures at least create an airflow component directed from the upper side portion to the lower side portion. Next to a downward component the airflow velocity in the combustion chamber preferably will also have a velocity component that is directed from the wall **21** towards the centre of the chamber.

[0027] Considering the air entering the combustion chamber through the upper and the lower apertures respectively it is preferred if the majority of air enters through the upper apertures. A favorable distribution appeared to be 75% of the air entering through the upper apertures, while the remaining 25% enters through the lower apertures. This can easily be established by choosing an appropriate ratio between the total aperture surface respectively at the bottom side portion and lower side portion.

[0028] The upper apertures **23** are arranged in 2 rows along the contour of the combustion chamber **12**. Preferably the apertures in a row are substantially evenly distributed along this contour. Furthermore it is preferred if apertures in both rows provide some kind of alternating perforation as is shown in FIG. **1** and more clearly in FIG. **2**. This has appeared to be advantageous with relation to the air that egresses from the combustion chamber. Moreover it is favorable with relation to having as many apertures as possible in a small surface.

[0029] An annular space **18** is formed between the cylindrical wall **21** and the housing **11**, which space acts as a preheat chamber. The annular space is filled with an air distributor **24** which preferably comprises a series of cylindrical metal sheets **24***a* with punched out ribs **24***b* maintaining separation between the sheets to provide air conduits. The metal sheets **24***a* guide the air flow and reflect heat back into the combustion chamber **12**, preheating the air that enters the combustion chamber through the upper air outlets **23** and ensuring that the outer surface of the housing **11** remains sufficiently cool in operation to be safe to the touch. The cylindrical metal sheets are held in place by a supporting structure **24***c*.

[0030] At the lower side portion **27** a supporting surface **29** for holding the solid fuel is disposed.

[0031] The airflow in the combustion chamber is such that a regular combustion process of solid particles arises. These particles can be any type of solid material, but preferably one uses wood. The present invention does not relate to fluidized bed types of combustion processes.

[0032] The base of the cylindrical vessel **21** includes a thermal isolation structure **25** which acts as a heat shield reducing downward radiation of heat towards an intermediate chamber **26** and a lower chamber **27** of the housing **11**. The intermediate chamber **26** and lower chamber **27** are separated by a wall **28** having openings (not shown). Adjacent to these apertures is mounted a blower assembly **50**, preferably having a central motor **52** and integral outwardly radiating blades

53 forming an impeller to direct air through the openings in the wall **28**. The central motor **52** is preferably protected by a further heat shield element **51**, which may be a thin layer of heat reflective material such as aluminium foil disposed on the motor. The lower chamber **27** is bounded by the housing **11** which includes the air inlets **14**.

[0033] In use, the blower assembly **50** draws air through the air inlets **14**, and blows it through the openings of the wall **28** into the intermediate chamber **26**. Intermediate chamber **26** acts as a distribution chamber to feed air into the annular space **13** and the air distributor **24**. Air flows between the sheets **24***a* of the air distributor **24** to warm the air and direct it to the lower and upper air inlets **22**, **23** of the combustion chamber **12**.

[0034] In one embodiment, the blower assembly or fan **50** comprises a 1 W brushless DC fan driven by a 3 to 7 V power supply (not shown), compatible with a 5 V motor. In another embodiment, the fan is a 12 V driven by a 6 to 14 V power supply. The power supply typically is an internally mounted battery accessible from the base of the stove. Alternatively an external supply may be used, whenever available. Tests have shown that the stove **11** is capable of boiling a litre of water in 4 minutes, without significant soot and smoke, with a combustion temperature of more than 1000° C. Food may be simmered at the lower voltage range or boiled at the higher voltage range thereby providing good cooking control.

[0035] The intermediate chamber **26** preferably is provided with a thermoelectric element **31** that has a first active surface in close proximity to the combustion chamber **12** and a second active surface positioned to receive a cooling draught from the blower assembly **50**. In the preferred arrangement shown, the second active surface of the thermoelectric element is in direct thermal association with, or forms part of, a heat sink arrangement **32** which is cooled by the fan. The first active surface of the thermoelectric element may be in close direct contact with a lower wall of the combustion chamber **12**, or isolation structure **25**. The thermoelectric element **31** may be embedded into the isolation structure **25** to increase the temperature available at the first active surface. In view of the heat shielding effects of the thermoelectric element **31** and heat sink **32**, a separate heat shield for motor **52** might not be required with this arrangement.

[0036] The thermoelectric element **31** is any suitable device that converts heat energy to electrical energy, such as a thermocouple or Peltier element. Such thermoelectric elements conventionally generate a voltage based on the thermal gradient across the device between a first and second active surface thereof. The thermoelectric element provides electrical power to the blower assembly **50**. In use, the blower assembly **50** provides airflow to the heat sink **32** and thermoelectric element **31** as well as to the air distributor **24**. In this manner, the second active surface of the thermoelectric element is maintained at a substantially lower temperature than would otherwise be the case, which increases the power output available from the element, and thus increases the available airflow to the combustion chamber **12**.

[0037] An electronic control unit **33** controls the blower assembly or fan and is also housed in the lower chamber **27**, where it is also protected from the heat of the stove. The electronic control unit **33** includes a rechargeable battery and a controller configured to operate the stove. The thermoelectric element provides electrical power to the fan **50** and the rechargeable battery, therewith extending the lifetime of the battery. In the preferred embodiment, the electronic control unit is adapted to automatically sequence through each of the available modes of the woodstove, such as a start-up or a shutdown mode. Preferably the electronic control unit adapts the subsequent steps according to the sensed operating conditions, e.g. heat of the fire. A temperature sensor (not shown) may be used to determine the heat of combustion, or this may be deduced from the electrical output of the thermoelectric element **31**.

[0038] Normally the rechargeable battery is only used to supply power in a start-up phase. In normal operation the battery can then sufficiently be re-charged by the thermoelectric element for the next start-up.

[0039] FIG. **3** shows a cross-section according to line I-I in FIG. **2** showing one of the apertures in more detail. It shows a part of the cylindrical wall in detail and illustrates that an upper edge **61** of the apertures is inclined inwardly with relation to the combustion chamber. A lower edge **62** is inclined outwardly with relation to the combustion chamber. Preferably the cylindrical wall comprises a heat resistant metallic sheet, such as stainless steel. This allows any airflow coming in through the aperture will be directed downwards, i.e. from the upper side portion of the combustion chamber to its lower side portion. This is especially advantageous in case of a relatively thin wall, wherein it is easier to deform the wall around the apertures. When the wall is somewhat thicker the apertures may comprise drilling holes having an inclined pitch with relation to the wall. In this case the wall of the combustion chamber will remain substantially flat.

[0040] An alternative advantageous embodiment is to have guiding means comprising nozzles having an outlet directed from the upper side portion to the lower side portion. An outlet of the nozzle may extend through the wall of the combustion chamber. Alternatively such nozzles may be arranged outside the combustion chamber at the upper side portion thereof.

[0041] When the airflow A in FIG. **3** encounters an airflow B flowing through an opposite aperture both flows will influence each other while creating a turbulent air mixture, which is believed to be torus shaped. Experiments have indicated that the airflow significantly contributes to a cleaner combustion process.

[0042] The simplest way to create an aperture shown in FIG. **3** is to stick a tool, such as a metal rod through an aperture having straight edges. Subsequently one tilts the tool, while the part outside the combustion chamber inclines upwards. Herewith one plastically deforms the edges of the aperture. Preferably the diameter of the metal rod is slightly smaller than the diameter of the aperture. This provides for a simple and reliable method of creating appropriate apertures.

[0043] In order to develop the required airflow certain sizes and number of apertures are preferred. Considering the fact that the stove is meant for cooking the thermal power that is wanted is in the range of 2-5 kW. That determines, in turn, a combustion rate in terms of gram wood per minute. That, in turn, determines the required airflow. A very significant surplus of air is used to ensure clean combustion. After careful experiments the required airflow was found to be in the range of 100 l/minute for the low power setting and 200 l/minute for the high power setting. Approximately 75% of the air is used as secondary combustion air.

[0044] A larger number of small apertures are preferred over a small number of large apertures. An optimum was found at 64 apertures of 2.5 mm in diameter.

[0045] A small improvement of the combustion properties was found by using two rows of 32 apertures displaced vertically by a few mm. Each row is arranged at some distance from the upper side portion. Preferably both rows are arranged in an alternating configuration. This arrangement appeared to result in an even better mixing of the combustible gasses with the available air. Typical outer dimensions of the woodstove are a height of 30 centimeter and a diameter of 20 centimeter.

[0046] The woodstoves according to the present invention is typically applied for in house cooking, wherein one benefits from the clean combustion process. However the woodstove can also be applied outdoors, such as during camping, since it usually can operate on (rechargeable) batteries. Another possible field of application is disaster areas, when people are in need for fires that are easy to establish with relation to (emergency) cooking and providing warmth.

[0047] A significant advantage of the design of stove described above is that the fan is sufficiently protected from the direct source of heat that a cheap mass produced motor with plastic components may be used, even though placed at only a short distance from the combustion chamber, resulting in a compact stove. Such motors also prove to be much more reliable and have a longer design life. Positioning of the motor in the supply air stream means that the motor is self-cooling, and also can be conveniently used to cool the cool side of the thermoelectric element.

[0048] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

[0049] The invention relates to a solid fuel stove comprising a combustion chamber (**12**) for containing combustion fuel and a blower assembly (**50**) configured to provide airflow entering the combustion chamber in operating condition. When guiding means (**40**) establish airflow entering the combustion chamber substantially in a downwardly direction the combustion process of the stove is very clean and efficient.

1. Solid fuel stove (**10**) comprising:

a combustion chamber (**12**) for containing combustion fuel, which chamber has a lower side portion (**17**) for accommodating fuel and an upper side portion (**15**);

a blower assembly (**50**) configured to provide airflow entering the combustion chamber in operating condition;

guiding means (**40**) to direct the airflow into the combustion chamber;

wherein the guiding means (**40**) direct the airflow from the upper side portion to the lower side portion.

2. Stove (**10**) as claimed in claim **1**, wherein the guiding means (**40**) comprise a plurality of apertures (**23**) provided in a wall (**21**) of the combustion chamber (**12**) at the upper side portion (**15**).

3. Stove (**10**) as claimed in claim **2**, wherein the upper edge (**61**) of an aperture is inclined inwardly with relation to the combustion chamber (**12**) and a lower edge (**63**) of an aperture is inclined outwardly with relation to the combustion chamber.

4. Stove (**10**) as claimed in claim **2**, wherein the apertures (**23**) comprise drilling holes having an inclined pitch with relation to the wall (**21**).

5. Stove (**10**) as claimed in claim **2**, wherein the apertures (**23**) are substantially evenly distributed along the contour of the combustion chamber.

6. Stove (**10**) as claimed in claim **2**, wherein each aperture (**23**) is disposed at a distance from the upper side portion.

7. Stove (**10**) as claimed in claim **1**, wherein the guiding means (**40**) establish airflow at the lower side portion of the combustion chamber.

8. Stove (**10**) as claimed in claim **7**, wherein the guiding means (**40**) comprises a plurality of apertures (**22**) at the lower side portion (**17**) of the combustion chamber (**12**).

9. Stove (**10**) as claimed in claim **1**, wherein a preheat chamber (**18**) disposed around the combustion chamber, which preheat chamber provides air flow communication from the blower assembly into the combustion chamber and comprises an air distributor (**24**) including heat reflectors (**14*a***) adapted to reflect heat radiated from the combustion chamber (**12**) back towards the combustion chamber.

10. Stove (**10**) as claimed in claim **1**, wherein a rechargeable electrical power source for driving the blower assembly and a thermoelectric element (**31**) are provided, and wherein the thermoelectric element is configured to provide power to the blower assembly and to the rechargeable power source.

11. Stove (**10**) as claimed in claim **1**, wherein the blower assembly (**50**) comprises a DC brushless motor (**52**) and an impeller (**53**) coupled thereto.

12. Stove (**10**) as claimed in claim **1**, wherein an electronic control unit (**33**) is provided, which unit is adapted to supply variable driving power to the blower assembly (**50**) to control the combustion temperature in the stove.

* * * * *