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(54) Device and method to control combustion in a heating apparatus

(57) Device to control combustion in a solid fuel heating apparatus (11), having an entrance aperture (15) suitable for the entrance of comburent air, a combustion chamber (17) for the solid fuel and an exit aperture for the fumes (22) produced in the combustion chamber (17). The device comprises measuring means (29, 35) suitable to measure directly the flow rate of the comburent air.

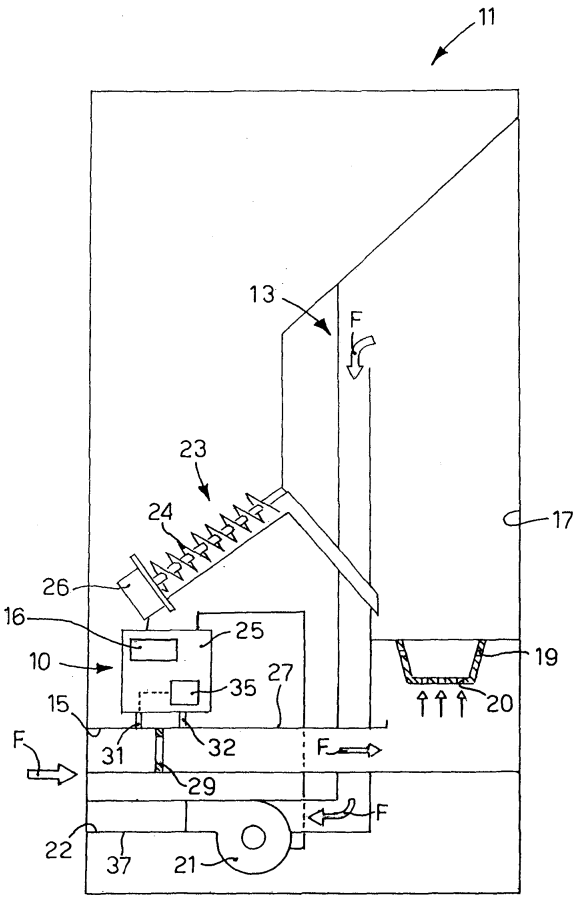

fig. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention concerns a device and a method to control the combustion in a heating apparatus, such as a stove, a fireplace, a heater or suchlike, fed with solid fuel, such as but not restrictively pellets, that is small pieces made from wood shavings, dried and pressed, chipped wood, blocks of wood, coal, other solid biomass fuels or other solid fuel material.

BACKGROUND OF THE INVENTION

[0002] The combustion of a woody biomass is known, which is carried out in a first step in which the water evaporates from the biomass, and a subsequent step in which the pyrolysis process occurs. During the gasification of the biomass, carbon is released which, in the presence of oxygen, is involved in the combustion. When this takes place inside a heating apparatus, the contribution of oxygen for the combustion is supplied by a flow of comburent air coming from the outside and having a determinate flow rate. The quantity of oxygen consumed in each of the combustion steps is different, therefore the flow rate of air used to feed the combustion is variable.

[0003] A stove using pellets is known which comprises loading means having a dosage system, such as a motorized Archimedean screw, which introduces the pellets to be burned into a combustion chamber, and a circuit for the comburent air, suitable to supply the oxygen needed for the combustion to the combustion chamber. The circulation of the comburent air inside the pellet stove is regulated by means of a fan for the extraction of fumes, placed in the terminal part of the circuit of the comburent air, in proximity to the exit aperture of the fumes. The power regulation of the known stove is achieved by regulating both the flow of the pellets introduced into the combustion chamber, and also the power of the fan for extracting the fumes exiting from the combustion chamber. Both these operations are carried out by an electronic control unit, inside the stove, connected both to the motorized Archimedean screw and also to the fan to extract the fumes.

[0004] To optimize the process of combustion depending on the hourly quantity of solid fuel, the flow rate of comburent air is determined experimentally, based on laboratory trials conducted by the same designers of the stove. The electronic control unit is designed and set to regulate the power supplied to the fan for the extraction of fumes in ratio to the quantity of fuel introduced into the combustion chamber. The ratio between the functioning power of the fan for the extraction of fumes and the flow rate of the comburent air entering the stove is also established experimentally.

[0005] Therefore the pellet stove of the known type has the disadvantage that the ratio between the power supplied to the fan for the extraction of fumes and the flow rate of entering air is only presumed and predetermined during the planning step, and therefore the actual flow rate of comburent air introduced into the combustion chamber can also be very different from the theoretical one. Indeed the entrance of the comburent air can be obstructed for any reason, for example by the excessive quantity of pellets loaded into the combustion chamber, which obstructs the entrance holes of the air. Moreover, the quantity of air taken in by the fan for the extraction of fumes can also be influenced by possible losses of load in the exit pipe or the chimney.

[0006] In some types of application the need is also known to duct the entrance pipe of the comburent air inside the exit pipe of the fumes, achieving a configuration of concentric double tubes. This is done, for example, to hermetically seal the combustion chamber and pre-heat the incoming comburent air.

[0007] Document US-A-5,873.356 describes a known pellet stove which includes an entrance pipe of the comburent air associated with a brazier and provided with hot wire sensor means to measure the flow of incoming comburent air. This known solution has at least the disadvantage that, if a configuration of concentric double tubes has to be achieved, the temperature of the air can reach high values which are not compatible with the correct functioning of the hot wire sensor means.

[0008] Document WO-A-2009/047249 describes a known device to measure and regulate the flow rate of comburent air entering the combustion chamber of a pellet stove. This known device comprises a Venturi tube disposed in the entrance pipe with its axis of development parallel to the longitudinal axis of the tube. The Venturi tube is configured to be passed through only by a part of the incoming air flow. The Venturi tube is directly associated with a first sensor, formed by a nozzle directly connected in correspondence to a narrowing obtained along the longitudinal extension of the Venturi tube. The first sensor also comprises a tube made of silicone or other heat resistant material which connects the nozzle to a first pressure sensor transducer, which directly measures the absolute pressure value of the air in the Venturi tube, and therefore the speed of the air, using the known energy conservation law in the form of the Bernoulli equation. Moreover, this known device can comprise a second sensor, similar to the first sensor, disposed upstream of the Venturi tube, directly connected with the zone of the entrance pipe upstream of the Venturi tube and downstream of the entrance aperture of the comburent air and also configured to determine the absolute pressure value, and therefore speed, of the air, in this case upstream of the Venturi tube. Furthermore an annular diaphragm can be provided, disposed downstream of the Venturi tube and which can be mounted, in a releasable way using screws for example, coaxial to the inside of the entrance pipe of the air in order to reduce the maximum flow rate of the incoming comburent air as a function of the characteristics of the stove and in particular of the combustion chamber, keeping the cross section of the

entrance of the entrance pipe of the comburent air standardized. This known device is, however, complex and costly to make both mechanically and in terms of control, since it has to manage absolute values of pressure measurement. The Venturi tube is limited to measurements in the delivery range from a few m^3/hr to thousands of m^3/hr. Moreover, a considerable disadvantage is represented by the distance between the pressure intakes, in that the low pressure intake is in the narrow part of the Venturi tube, while the high pressure intake must be placed at a certain distance from this, so as to not to be affected by the contracted vein, in practice at about 7 - 10 internal diameters of the tube distant from the narrow part, which may result in a very bulky measuring device.

[0009] Document DE-U-202004020320 describes a solid fuel heater which comprises a control device of the air having a pressure intake upstream and a pressure intake downstream of the combustion chamber. This known control device suffers from the disadvantage, already mentioned earlier, that possible clogging of the brazier, and also possible internal losses, can be confused with differences in pressure linked to the flow rate of incoming air and therefore does not give a correct indication of the comburent air entering the combustion chamber, and does not allow an efficient control of the combustion.

[0010] Document DE-U-20216653 describes a solid fuel stove which comprises an entrance pipe of the comburent air provided with a sensor of the quantity of incoming air.

[0011] Document WO-A-2006/081600 describes a heating device using pellets provided with a safety sensor associated with the entrance pipe of the comburent air, in order to detect the lack of incoming air.

[0012] One purpose of the present invention is to obtain a device to control and optimize the combustion of a heating apparatus in any operating condition which, in particular, overcomes the disadvantages of the state of the art and which is also simple to make mechanically and not at all bulky.

[0013] Another purpose of the present invention is to obtain a method which allows to control the combustion on the basis of the power required by the heating apparatus, irrespective of operating and/or installation conditions.

[0014] The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other purposes and advantages.

SUMMARY OF THE INVENTION

[0015] The present invention is set forth and characterized in the independent claims, while the dependent claims describe other characteristics of the invention or variants to the main inventive idea.

[0016] In accordance with the above purposes, a device according to the present invention to control combustion is installable in a heating apparatus using solid fuel, such as for example a pellet stove, having an entrance aperture, suitable for the entrance of comburent air, a combustion chamber for the solid fuel, an entrance pipe disposed between the entrance aperture and the combustion chamber and a exit aperture for the combustion fumes.

[0017] According to a feature of the present invention, the device comprises measuring means to measure the flow rate of the comburent air. The measuring means allow to carry out a precise adjustment of the flow rate of incoming comburent air, not in a theoretical and predetermined way, but on the basis of the comburent air actually introduced into the combustion chamber.

[0018] According to the present invention, the measuring means are disposed in proximity to the entrance aperture and comprise perturbation means to perturb the flow of comburent air along the entrance pipe, configured to be passed through by the whole flow of incoming comburent air from the entrance aperture along the entrance pipe, and a pressure gauge applied to the entrance pipe to measure the difference in pressure of the comburent air upstream and downstream of the perturbation means.

[0019] According to a variant of the present invention, the measuring means comprise a speed measurer, of any type, to measure the speed of the comburent air in the entrance pipe.

[0020] According to another feature of the present invention, electronic control means, which comprises an electronic control unit for example, are associated with the measuring means in order to command, on the basis of the data coming from the latter, motorized means to expel the fumes, which comprise a fan or a suction fan for example, and/or motorized means to feed the solid fuel, which for example comprise an Archimedean screw commanded by an electric motor.

[0021] In this way a real and effective control of the combustion of the heating apparatus is obtained, because both the flow rate of the solid fuel in the combustion chamber and the exit of the fumes can be regulated, depending on the actual flow rate of comburent air entering into the combustion chamber.

[0022] According to another variant, if the heating apparatus is already provided with an electronic control unit, or other means of control, the means for measuring the flow rate of comburent air can be directly associated to them.

[0023] According to one form of embodiment of the present invention, the difference in pressure of the system of perturbed flow in the entrance pipe is interpreted as an index of the quantity of comburent air which actually enters the wood pellet stove. This index is associated with an indication of quality, good or not, of the combustion, based on a comparison with actual experimental data of the quantity of incoming air measured by the designers of the stove in conditions of optimal combustion and memorized in at least an electronic data base in memorization means associated with electronic control

means.

[0024] The present invention obtains a measuring device which is simple to make, even mechanically, and not very bulky, as well as being reliable in optimizing the combustion and which is not affected by losses in the combustion chamber or the clogging of the brazier.

[0025] Another advantage of the present invention is that it can be used, without being influenced by the temperature, even in the case where a configuration of concentric double tubes must be made, where the entrance pipe of the air is ducted into the exit pipe of the fumes. Indeed, the simple mechanical achievement of perturbation means and the differential measurement of the flow rate according to the invention is not affected in any way by possible high temperatures of the incoming air, thus providing reliable measurements.

[0026] The present invention also concerns a method to control combustion in a solid fuel heating apparatus, having an entrance aperture suitable for the entrance of comburent air, a combustion chamber for the solid fuel and an exit aperture for the fumes produced in the combustion chamber.

[0027] According to a characteristic feature of the present invention, the method comprises a step of measuring the flow rate of the comburent air.

[0028] According to another characteristic feature of the present invention, an adjustment step follows the measuring step, during which control means, of the device itself and/or of the heating apparatus in which the device is installed, are able to command motorized means to expel the fumes and/or to feed the solid fuel, depending on the flow rate of comburent air measured during the measuring step.

[0029] According to one form of embodiment, the method of the present invention provides to memorize, in memorization means of the control means, at least an electronic data base comprising one or more tables which comprise values of the flow rate of incoming comburent air, predetermined experimentally for each specific heating apparatus or series of heating apparatuses associated with a plurality of indexes correlated to the quality of combustion in the combustion chamber of the specific heating apparatus or series of heating apparatuses. Moreover the adjustment step provides to command the motorized expulsion means and/or motorized feed means depending on the outcome of a comparison between the indication of air flow rate supplied on each occasion during the measuring step and the index correlated to the quality of the combustion in the combustion chamber associated, in the tables, with the indication of air flow rate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] These and other characteristics of the present invention will become apparent from the following description of a preferential form of embodiment, given as a non-restrictive example with reference to the attached drawings wherein:

- fig. 1 is a lateral view, schematized and sectioned, of a device according to the present invention, installed in a heating apparatus;
- fig. 2 is an enlarged detail of the device in fig. 1.

DETAILED DESCRIPTION OF A PREFERENTIAL FORM OF EMBODIMENT

[0031] With reference to fig.1, a device 10 according to the present invention is installed in a solid fuel heating apparatus 11, which in this case, given as a non-restrictive example, is a biomass stove, for example of the wood pellet type, to control the combustion. In the following description, for ease of explanation, the heating apparatus will be referred to as a stove 11, however the present description shall also apply for other types of heating apparatuses. The stove 11 comprises a circuit 13 for the comburent air and fumes, which extends from an entrance aperture 15 to an exit aperture 22, according to a flow indicated by F. The stove 11 also comprises a combustion chamber 17, an entrance pipe 27 for the comburent air, located below the latter, and a fan 21, or equivalent motorized expulsion means, for the extraction of the fumes, located in an exit pipe 37 of the fumes, in proximity to the exit aperture 22. The combustion chamber 17 comprises a brazier 19 provided with through holes 20, through which, by depression, comburent air enters coming from the entrance pipe 27.

[0032] The stove 11 also comprises motorized feed means 23, suitable to introduce the pellets into the brazier 19 and in this case consisting of an Archimedean screw 24 connected to an electric motor 26.

[0033] The device 10 comprises measuring means, in this case static, to measure the flow rate of the incoming comburent air, which comprise means to perturb the flow of air along the entrance pipe 27, configured to be passed through by the whole flow F of incoming comburent air from the entrance aperture 15 along the entrance pipe 27. In a variant embodiment, the perturbation means comprise a diaphragm, or calibrated mouth 29, of an annular shape (figs. 1 and 2), disposed inside the entrance pipe 27 and conformed so as to reduce the transverse section thereof. In the variant with a diaphragm, a narrowing in the entrance pipe 27 is defined, generating a localized loss of load in the narrow zone. The pressure, in particular, will be higher upstream of the diaphragm 29 and lower downstream of the diaphragm 29. Measuring the difference in pressure between upstream and downstream, normally proportional to the square of the speed through the diaphragm 29, the flow rate can be calculated. The specific solution with the diaphragm 29 has an optimum precision, in the order of 0.5% of the measurement and it adapts to measurements of very small flow rates, in the order of some cm^3/hr up to very big ones, in the order of thousands of m^3/hr. The measuring means also comprise a pressure gauge 35, which

is disposed in proximity to the perturbation means, in this case exemplified by the diaphragm 29, outside the entrance pipe 27, to measure the pressure of the comburent air by means of two tubes 31 and 32, located upstream and respectively downstream of the perturbation means, in this case exemplified by the diaphragm 29. The pressure measurer 35 in this case is suitable to measure a difference in pressure comprised between about 0 Pa and about 500 Pa.

[0034] An electronic control unit 25, or other electronic control means, for example a suitable electronic control card, is electrically connected to the pressure gauge 35, is able to supply an indication of the actual speed, and therefore the actual flow rate of the comburent air in the entrance pipe 27, on the basis of the difference in pressure measured by the pressure gauge 35.

[0035] In some forms of embodiment of the present invention, the pressure gauge 35 is integrated into the electronic control unit 25. Advantageously, the pressure gauge 35 makes a digital signal available, correlated to the measurement, which is directly usable by the electronic control unit 25.

[0036] According to one form of embodiment, the electronic control unit 25 comprises memorization means 16 which include at least an electronic data base comprising one or more tables which comprise values of flow rate of incoming comburent air predetermined experimentally, in the design or construction step, for each specific heating apparatus 11 or series of heating apparatuses 11 and associated with a plurality of indexes correlated to the quality of the combustion in the combustion chamber 17 of the specific heating apparatus 11 or series of heating apparatuses 11.

[0037] The electronic control unit 25 is configured to command the fan 21 and/or the motorized feed means 23 depending on the outcome of a comparison between the indication of the flow rate of air supplied on each occasion by the pressure gauge 35 and the index correlated to the quality of the combustion in the combustion chamber 17 associated in the tables with the indication of flow rate of air.

[0038] The device 10 described heretofore functions as follows.

[0039] The electronic control unit 25 commands the electric motor 26 of the Archimedean screw 23 so as to selectively adjust the flow rate of the pellets introduced into the brazier 19 and, on the basis of that rate, also establishes the flow rate of the comburent air needed, depending on the comparison carried out with the data included in the memorization means 16 in order to optimize the combustion of the pellets inside the combustion chamber 17. The same electronic control unit 25 is also able to verify, in continuous mode, the actual flow rate of the comburent air introduced through the entrance pipe 27, by means of the pressure gauge 35 and to vary, if necessary, the functioning power of the fan 21 so as to keep the flow rate of the incoming comburent air constant, at the pre-established value, depending on the data included in the memorization means 16.

[0040] In the case where a possible obstacle in the circuit 13, for example an obstruction of the through holes 20 of the brazier 19, caused by the pellets themselves, or other, causes a loss of load and therefore a reduction in the actual flow rate of incoming comburent air, the electronic control unit 25 is able to intervene, increasing the power supplied to the fan 21 in order to increase the suction and therefore return the flow rate of comburent air to the pre-established value.

[0041] It is clear that modifications and/or additions of parts may be made to the device to control combustion as described heretofore, without departing from the field and scope of the present invention.

[0042] For example, in alternative variants of the present invention, the perturbation means may consist of an "S" conformation of the entrance pipe, or by a narrowing in section of a different or irregular shape, or other means able to determine a perturbation as homogeneous as possible in the flow of comburent air entering the stove which determines a difference in pressure which can be measured and associated with an index of quantity of incoming comburent air.

[0043] In another variant of the present invention, the entrance pipe 27 can be ducted in the exit pipe 37 of the fumes, achieving a configuration of concentric double tubes.

[0044] It is also clear that, although the present invention has been described with reference to some specific examples, a person of skill in the art shall certainly be able to achieve many other equivalent forms of device to control combustion, having the characteristics as set forth in the claims and hence all coming within the field of protection defined thereby.

Claims

1. Device to control combustion in a solid fuel heating apparatus (11), having an entrance aperture (15) suitable for the entrance of comburent air, a combustion chamber (17) of said solid fuel, an entrance pipe (27) disposed between said entrance aperture (15) and said combustion chamber (17), and an exit aperture for the fumes (22) produced in said combustion chamber (17), **characterized in that** it comprises measuring means suitable to directly supply an indication of the flow rate of said incoming comburent air and disposed in proximity to said entrance aperture (15), said measuring means comprising means (29) to create a perturbation in the flow (F) of comburent air along said entrance pipe (27), configured to be passed through by the whole flow (F) of comburent air entering from the entrance aperture (15) along the entrance pipe (27) and a pressure gauge (35), applied to said entrance pipe (27), to measure the difference in pressure of said comburent air upstream and downstream of said perturba-

tion means (29).

2. Device as in claim 1, **characterized in that** it also comprises control means (25) of the electronic type associated to said measuring means (29, 35) to command motorized expulsion means (21), suitable to selectively force the expulsion of the fumes through said exit aperture of the fumes (22), and/or motorized feed means (23), suitable to selectively feed said solid fuel into said combustion chamber (17).

3. Device as in claim 2, **characterized in that** said control means (25) comprise memorization means (16) which include at least an electronic data base comprising one or more tables which comprise flow rate values of the incoming comburent air, predetermined experimentally for each specific heating apparatus (11) or series of said heating apparatuses (11) associated with a plurality of indexes correlated to the quality of the combustion in the combustion chamber (17) of the specific heating apparatus (11) or series of said heating apparatuses (11), said control means (25) being configured to command said motorized expulsion means (21) and/or motorized feed means (23) as a function of the outcome of a comparison between the indication of the air flow rate supplied on each occasion by the measurement means (29, 35) and the index correlated to the quality of the combustion in the combustion chamber (17) associated in said tables with said indication of the air flow rate.

4. Device as in claim 1, 2 or 3, **characterized in that** said perturbation means comprise a diaphragm (29) which defines a narrowing of the cross section of said entrance pipe (27).

5. Device as in claim 4, **characterized in that** said pressure gauge (35) is suitable to measure a difference in pressure comprised between about 0 Pa and about 500 Pa.

6. Device as in any claim hereinbefore, **characterized in that** the pressure gauge (35) is associated with two tubes (31, 32) both directly connection with the inside of the entrance pipe (27), of which a first tube (31) is disposed upstream of the perturbation means (29) and a second tube (32) is disposed downstream of the perturbation means (29).

7. Method to control combustion in a solid fuel heating apparatus (11), having an entrance aperture (15) suitable for the entrance of comburent air, a combustion chamber (17) for said solid fuel and an exit aperture for the fumes (22) produced in said combustion chamber (17), **characterized in that** it comprises a step of measuring the flow rate of said incoming comburent air in proximity to said entrance aperture (15), the measuring step comprising a perturbation of the flow (F) of comburent air along said entrance pipe (27) and a measurement of the difference in pressure of said comburent air upstream and downstream of said perturbation.

8. Method as in claim 7, **characterized in that** it also comprises an adjustment step, subsequent to said measuring step, in which control means (25) command motorized expulsion means (21) in order to selectively force the expulsion of the fumes through said exit aperture of the fumes (22), and motorized feed means (23), in order to selectively feed said solid fuel into said combustion chamber (17), as a function of the flow rate of the comburent air measured in said measuring step.

9. Method as in claim 8, **characterized in that** it provides to memorize, in memorization means (16) of said control means (25), at least an electronic data base comprising one or more tables which comprise values of the flow rate of incoming comburent air, experimentally predetermined for each specific heating apparatus (11) or series of said heating apparatuses (11) associated with a plurality of indexes correlated to the quality of combustion in the combustion chamber (17) of the specific heating apparatus (11) or series of said heating apparatuses (11) and **in that** said adjustment step provides to command said motorized expulsion means (21) and/or motorized feed means (23) as a function of the outcome of a comparison between the indication of air flow rate supplied on each occasion during the measuring step and the index correlated to the quality of the combustion in the combustion chamber (17) associated, in said tables, with said indication of air flow rate.

10. Solid fuel heating apparatus, comprising an entrance aperture (15) suitable for the entrance of comburent air, a combustion chamber (17) for said solid fuel and an exit aperture for the fumes produced in said combustion chamber (17), **characterized in that** it also comprises a device (10) to control the combustion as in any claim from 1 to 6.

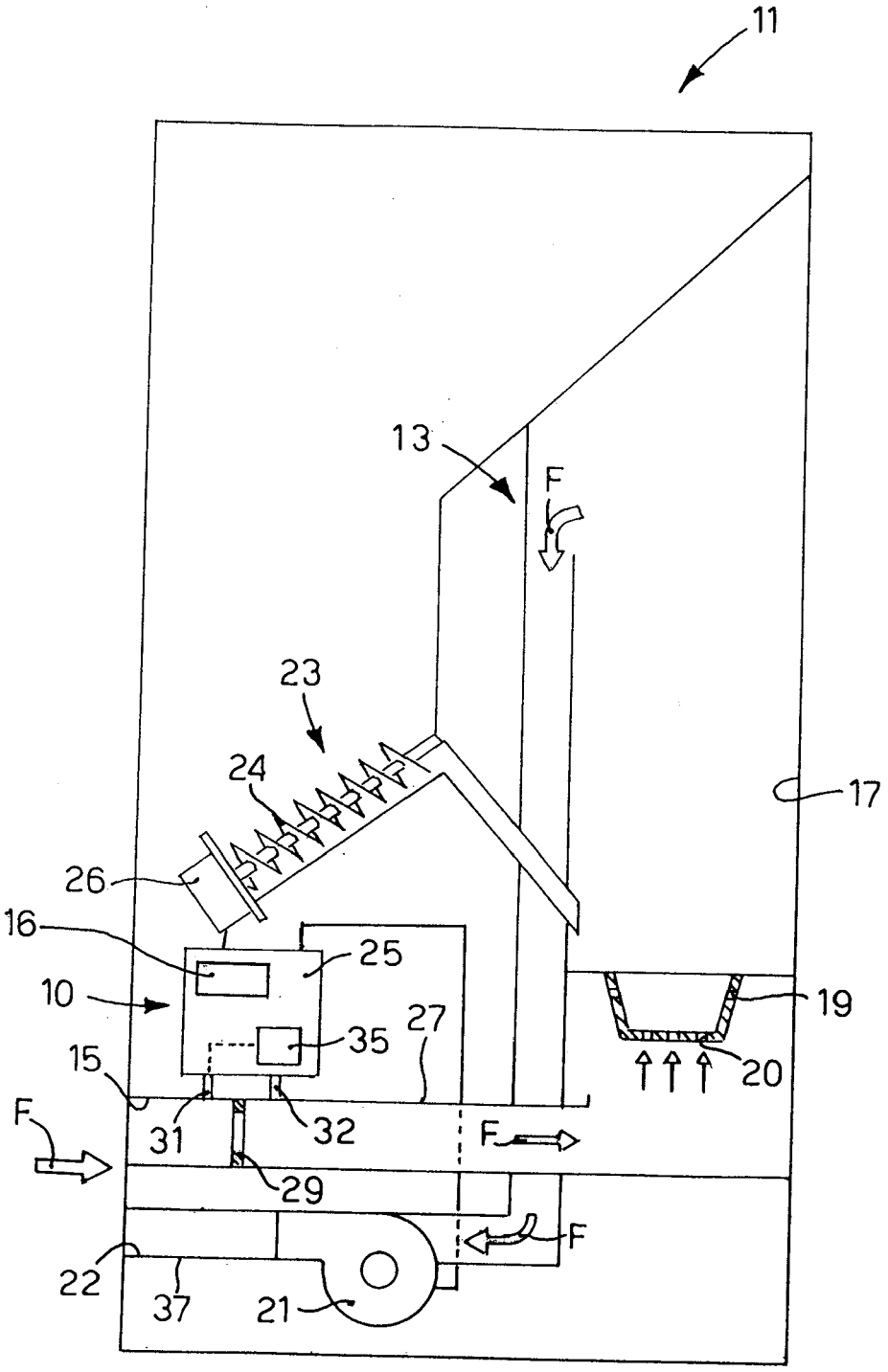

fig. 1

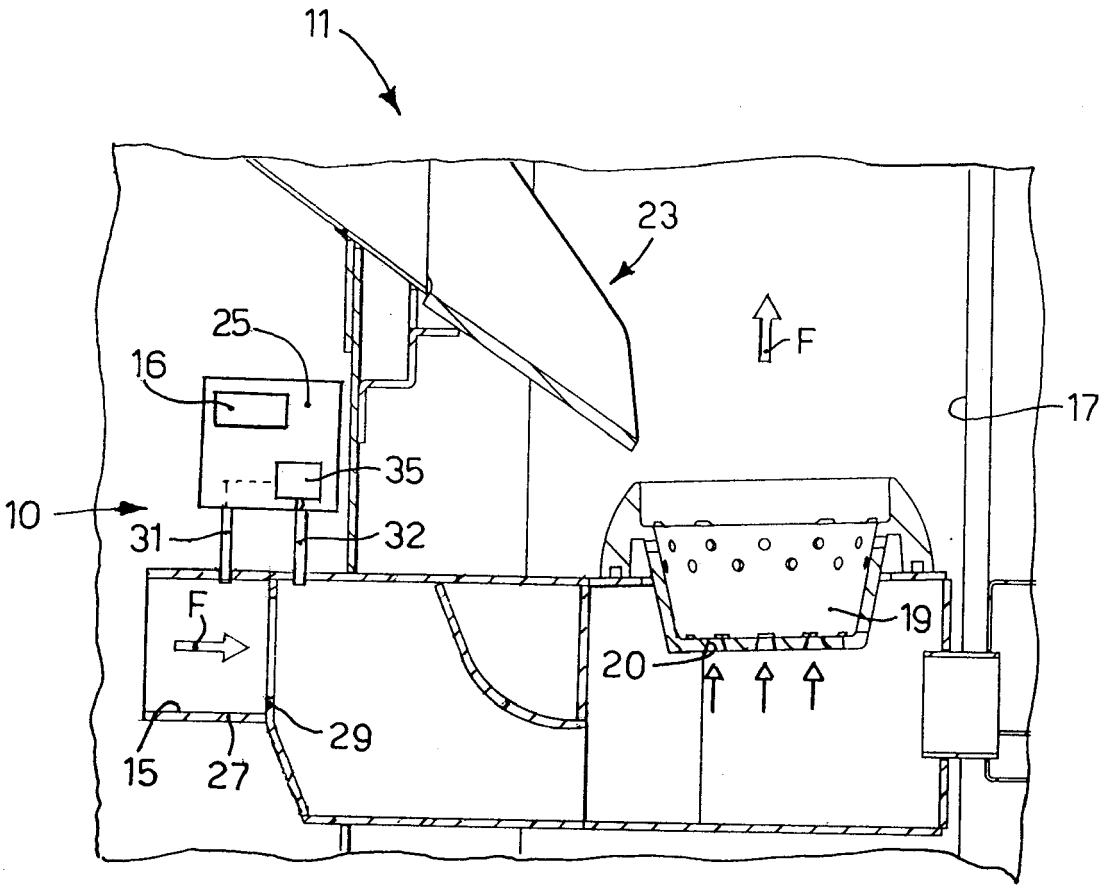

fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 12 15 5548

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 May 2012	Coli, Enrico

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 15 5548

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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