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(54) **Multiphase method for controlling an air flow into the hearth of a fireplace for solid fuels, especially wood**

(57) The object of the present invention is a multiphase method for controlling an air flow into the hearth of a fireplace for solid fuels, especially wood, within a system comprising the said fireplace with the hearth, an intake air damper (2), a sensor (3) of combustion gas temperature, a water jacket connected to a heating circuit through at least one pump (5, 6, 7), a sensor (4) of water temperature in the water jacket and a controller (1), connected at least with the sensor (3) of combustion gas

temperature, with the sensor (4) of water temperature in the water jacket, with the intake air damper (2) and with at least one pump (5, 6, 7), characterised in that, by means of the sensor (3) of combustion gas temperature, temperature of combustion gases ($T_{\text{combustion gas}}$) produced as a result of solid fuel combustion in the fireplace hearth is measured, and depending on this temperature, the air flow to the hearth is controlled by controlling the opening of the intake air damper (2).

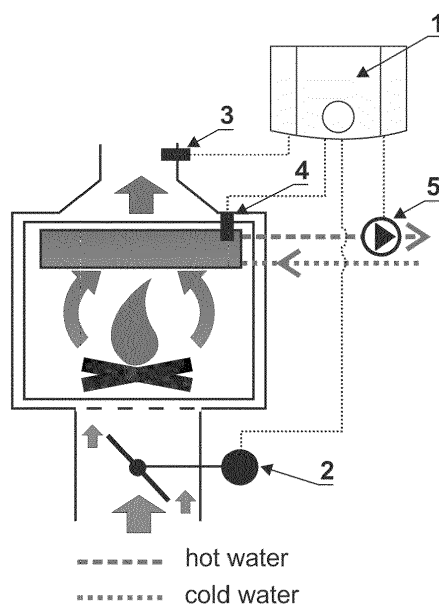


Fig. 1

Description

[0001] The object of the invention is a multiphase method for controlling an air flow into the hearth of a fireplace for solid fuels, especially wood.

[0002] For a long time, furnaces and fireplaces have been used to heat houses and flats. In recent years, the effectiveness of such furnaces has constantly increased. However, in order to reduce consumption and costs of conventional fuels, there is still a need for higher efficiency of furnaces and fireplaces, and for a better control of room temperature, e.g. through the use of algorithm for controlling the air flow into the hearth.

[0003] Previously, devices for heating purposes had chimneys with open access to air which was not regulated in any manner. There were not any room temperature or combustion gas temperature meters, either. This resulted in that the room temperature increased only while adding wood to the furnace, and vice versa, it decreased during its absence.

[0004] Efficiency of furnaces has been improved by using air damper in the fireplace, the location of the said air damper depending on the value of room temperature, or - afterwards - on the combustion gas temperature.

[0005] In the prior art, there is a solution related to a solid fuel combustion appliance which has a sensor for sensing the output temperature of combustion gases and for sensing the amount of fuel (US 2011/0300494 A1). A control system controls the air damper in order to maintain the predetermined temperature, and at the moment of adding the fuel to the appliance, it temporarily stimulates the initial combustion of the new fuel before returning to maintaining the predetermined temperature of combustion gases (firing up). Air flow control can be performed by means of proportional differentiation or proportional integral differentiation methods. A disadvantage of such solutions is the impossibility of ensuring a constant temperature in the house which would be preferred by the user.

[0006] There are examples which use electronic or non-electronic system for controlling a heating device which heats up a heating medium (water or air in a suitable jacket), on the basis of at least two controlled temperatures.

[0007] For example, in the publication US 2011/0271948 A1, a device having a non-electronic control system for capturing heat from furnace and delivering this heat to a central heating system, as a supplement, is described. Sensors for sensing combustion gas and water temperatures in a heat exchanger ensure that in case the temperature of the incoming air is lower than the temperature of water in the central heating system, combustion gases are returned in the walls of the fireplace to a fan which directs the air flow straight into the heat exchanger. If the temperature of water is higher than the predetermined one, the fan turns off. A disadvantage of this solution is that this is only a supplement to the central heating already installed.

[0008] In another example (GB 836418 A), a control system for liquid fuel burners in devices having a chamber or a container adapted for heating a heating medium with its use, e.g. a water tank or a hot air chamber, comprising two parts, one of which responding to flame temperature in the vicinity of a burner, and the other one - to the temperature of the heating medium, is presented. The control element is a bimetallic lever arm which is susceptible to bending when being heated with a flame, thereby causing a fuel valve to close. In the case of reaching the predetermined water temperature in the tank, a thermostatic rod acts on the bimetallic arm which changes its position, thereby reducing the fuel flow. Therefore, it is a purely mechanical solution. A disadvantage of this solution is that the said structure does not provide for a connection of a container with heated water or air to the central heating system, as well as a large size and weight of the device which restrict the possibility of placing it anywhere in the building.

[0009] In turn, the publication WO 2012/061795 A2 presents an intelligent controller for a catalytic converter, which automatically controls a damper, a blower and an electric heater in a device fired with biofuel with respect to monitored temperature values: the input and output temperatures of a water jacket and the output temperature of the catalytic converter. The intake air damper is opened only at the time of reaching, by the (electrically heated) catalyst, the first predetermined temperature, and when the second predetermined temperature is reached, the blower turns on. In case the temperature difference at the inlet and outlet of the water jacket is higher than 20°F, the intelligent controller can open the damper and/or control the blower. If the temperature of the water jacket drops below the predetermined value, a boiler controller will open the air damper and will control the blower in order to burn the fuel and consequently heat the water. In addition, the device has a sensor for sensing a low water level in the jacket. In this case, the damper closes, and the working blower stops in order to extinguish the fire and prevent damage to the hearth or to the water jacket. There is not any information about a water pump and its control. A disadvantage of this solution is the lack of proceedings in the case of exceeding the maximum values of monitored temperatures, which can result in overheating the device, and the use of this type of controller only in furnaces for burning biofuel in the presence of a catalyst.

[0010] In the solution (WO 2010/092410 A2) an energy-efficient fireplace which, by using water or air as operating media, retrieves a large part of the energy produced by the combustion of solid fuels, is presented. An electronic system for controlling fire receives signals from various sensors (among others the ones for sensing the combustion gas and operating medium temperatures), regulates the operation of a supply air fan, which prevents the smoke from entering the house while the air inside the building is still being refreshed, and commissions actuators to regulate the position of an air damper and of

an air shutter. During the firing up of the fireplace and until the predetermined temperature is reached in the room, the intake air damper and the intake air shutter are open at 60° and while maintaining this temperature - at 30°. However, after exceeding the predetermined temperatures of combustion gases or heating medium, the intake air damper and the intake air shutter close even to 5°, which limits the amount of oxygen supplied to the hearth and thereby decreases the temperature of combustion gases. In addition, a control unit turns on the supply air fan at equal intervals in order to blow through the system. In the case, however, the overheating occurred, the central heating is an open system, which eliminates the risk of explosion. A disadvantage of this solution is that the control unit regulates the operation of the furnace only in relation to the predetermined maximum temperature of combustion gases and heating medium. However, it does not take account their minimum operating temperature, which can cause uneven heating of the house, and even its cooling down if there is not any fuel in the furnace. In addition, the heating medium in the said structure convectively moves along the central heating system, without the use of circulation pumps, which results in a too long time of heating the house to the predetermined temperature in the room.

[0011] In the present application, a solution which addresses these problems by introducing an algorithm for detecting an ending fuel in the fireplace chamber, by using water jacket pumps, the control of the air supply to the hearth and of the operation of pumps being integrated based on the measurement of temperatures of combustion gases and heating medium, especially water, is presented.

[0012] The object of the present invention is a multiphase method for controlling an air flow into the hearth of a fireplace for solid fuels, especially wood, within a system comprising the said fireplace with a hearth, an intake air damper, a sensor of combustion gas temperature, a water jacket connected to a heating circuit through at least one pump, a sensor of water temperature in the water jacket and a controller, connected at least with the sensor of combustion gas temperature, with the sensor water temperature in the water jacket, with the intake air damper and with at least one pump, characterised in that, by means of the sensor of combustion gas temperature, temperature of combustion gases ($T_{\text{combustion gas}}$) produced as a result of solid fuel combustion in the fireplace hearth is measured, and depending on this temperature, the air flow to the hearth is controlled as follows:

a) [firing up phase] the intake air damper is opened, resulting in substantial flow air into the hearth, and then the opening of the damper is controlled on the basis of proportional-integral-differentiation from the feedback of the combustion gas temperature signal until the measured combustion gas temperature ($T_{\text{combustion gas}}$) exceeds the predetermined value

of the firing up temperature ($T_{\text{firing up}}$), followed by

b) [automatic mode, phase I] the intake air damper is gradually and slowly closed in order to bring the observed combustion gas temperature ($T_{\text{combustion gas}}$) to the predetermined value of automatic operation temperature ($T_{\text{automatic operation}}$) based on an integrating algorithm which closes the intake air damper the faster, the further the value of combustion gas temperature ($T_{\text{combustion gas}}$) is from the predetermined temperature of automatic operation ($T_{\text{automatic operation}}$), followed by

c) [automatic mode, phase II] the combustion gas temperature ($T_{\text{combustion gas}}$) is maintained constant, by changing the opening of the intake air damper, the control of the intake air damper being performed on the basis of proportional-integral-differentiation from the feedback of the combustion gas temperature signal, and simultaneously

d) [detection of fuel shortage] the combustion gas temperature ($T_{\text{combustion gas}}$) is monitored and, in the controller, a prompt of fuel shortage is generated in the case where the following conditions are simultaneously met:

- the observed combustion gas temperature ($T_{\text{combustion gas}}$) is lower in relation to the predetermined temperature of automatic operation ($T_{\text{automatic operation}}$) by the value of $dT_{\text{fuel shortage}}$;
- the intake air damper remains opened, and the combustion gas temperature ($T_{\text{combustion gas}}$) decreases in time;
- combustion gas temperature ($T_{\text{combustion gas}}$) maintains a constant decreasing trend within 30 seconds;
- decreasing rate of combustion gas temperature ($T_{\text{combustion gas}}$) in time is not lower than the predetermined value of *Det. of fuel shrtg min*;
- decreasing rate of combustion gas temperature ($T_{\text{combustion gas}}$) in time is not higher than the predetermined value of *Det. of fuel shrtg max*;

e) [automatic mode, phase III] the intake air damper is controlled in a positive feedback, gradually closing the intake air damper together with a decrease in combustion gas temperature ($T_{\text{combustion gas}}$), and if the observed combustion gas temperature ($T_{\text{combustion gas}}$) starts to increase in time - a transition to phase c) [automatic mode, phase II] takes place,

f) [automatic mode, phase IV] from a few to several

hearth blowthroughs are performed by a complete opening of the intake air damper in order to check whether fuel was added to the hearth; if fuel was added and the observed combustion gas temperature ($T_{\text{combustion gas}}$) exceeds the predetermined value of operation temperature ($T_{\text{operation}}$), then a transition to phase c) [automatic mode, phase II] takes place; if fuel was not added and the observed combustion gas temperature ($T_{\text{combustion gas}}$), on completion of the blowthrough series, does not exceed the predetermined value of operation temperature ($T_{\text{operation}}$), then the process is completed.

[0013] Preferably, in addition, water heating circuit is controlled based on the water jacket temperature (T_{jacket}) measured by a sensor for sensing water temperature in water jacket, autonomously to controlling the air flow into the hearth.

[0014] In this case, preferably, at least one circulation pump of the central water heating circulation is attached only in the case if the water jacket temperature (T_{jacket}) exceeds the predetermined minimum value ($T_{\text{jacket operation}}$).

[0015] If additionally the water heating circuit is controlled based on the water jacket temperature (T_{jacket}) measured by a sensor of water temperature in water jacket, autonomously for controlling the air flow into the hearth or at least one circulation pump of the central water heating circulation is attached only if the water jacket temperature (T_{jacket}) exceeds the predetermined minimum value ($T_{\text{jacket operation}}$), then, preferably, at least one circulation pump of the central water heating circulation is always attached if the water jacket temperature (T_{jacket}) exceeds the predetermined maximum value ($T_{\text{jacket operation max}}$).

[0016] If additionally the water heating circuit is controlled based on the water jacket temperature (T_{jacket}) measured by a sensor of water temperature in water jacket, autonomously for controlling the air flow into the hearth or at least one circulation pump of the central water heating circulation is attached only if the water jacket temperature (T_{jacket}) exceeds the predetermined minimum value ($T_{\text{jacket operation}}$), or at least one circulation pump of the central water heating circulation is always attached if the water jacket temperature (T_{jacket}) exceeds the predetermined maximum value ($T_{\text{jacket operation max}}$), then, preferably, the at least one circulation pump of the central water heating circulation is always turned off if automatic mode phase IV for controlling the air flow into the hearth takes place.

[0017] Preferably, the value of firing up temperature parameter ($T_{\text{firing up}}$) ranges from 300 °C to 600 °C, more preferably from 400 °C to 500 °C, and most preferably from 450 °C to 500 °C.

[0018] Preferably, the value of automatic operation temperature parameter ($T_{\text{automatic operation}}$) ranges from 150 °C to 500 °C, more preferably from 200 °C to 400 °C, and most preferably from 250 °C to 350 °C.

[0019] Preferably, the value of operation temperature

parameter ($T_{\text{operation}}$) ranges from 80 °C to 255 °C, more preferably from 120 °C to 180 °C, and most preferably from 150 °C to 180 °C.

[0020] Preferably, the value of dT_{fuel} shortage parameter ranges from 10 °C to 60 °C, more preferably from 15 °C to 50 °C, and most preferably from 20 °C to 40 °C.

[0021] Preferably, the value of *Det. of fuel shrtg min* parameter ranges from 1 to 30, more preferably from 1 to 20, and most preferably from 1 to 5.

[0022] Preferably, the value of *Det. of fuel shrtg max* parameter ranges from 1 to 60, more preferably from 5 to 60, and most preferably from 20 to 60.

[0023] Preferably, the value of water jacket minimum temperature parameter ($T_{\text{jacket operation}}$) ranges from 20 °C to 60 °C, more preferably from 40 °C to 50 °C, and most preferably from 40 °C to 50 °C.

[0024] Preferably, the value of water jacket maximum temperature parameter ($T_{\text{jacket operation max}}$) ranges from 70 °C to 99 °C, more preferably from 80 °C to 95 °C, and most preferably from 89 °C to 91 °C.

[0025] Preferably, the predetermined combustion gas temperature being input to the algorithm is determined as an average fireplace temperature of the fireplace tests.

[0026] Preferably, the controller has access to a fireplace parameter database which contains individual characteristics of a given hearth and a value of at least one of the parameters: $T_{\text{firing up}}$, $T_{\text{automatic operation}}$, $T_{\text{operation}}$, $dT_{\text{fuel shortage}}$, *Det. of fuel shrtg min*, *Det. of fuel shrtg max*, $T_{\text{jacket operation}}$, $T_{\text{jacket operation max}}$, is read from this database.

Preferred Embodiment of the Invention

[0027] Now, the invention will be presented in greater detail in a preferred embodiment, with reference to the accompanying drawings in which:

Fig. 1 shows an operational configuration of the controller;

fig. 2 shows an algorithm for selecting an operation mode during start-up of the controller;

fig. 3 shows an operation diagram of the combustion circuit;

fig. 4 shows an operation algorithm;

fig. 5 shows a rate of temperature decrease;

fig. 6 shows the principle of operation of fuel shortage detection;

fig. 7 shows an operation diagram of the water jacket circuit; and

fig. 8 shows examples of application diagrams.

[0028] In the drawings, the following designations were used: 1 - controller; 2 - intake air damper; 3 - sensor of combustion gas temperature; 4 - sensor of water jacket temperature; 5 - circulation pump of the central heating circulation; 6, 7 - additional pumps; 8 - boiler; 9 - container; 10 - heating circuit exchanger; 11 - heating system.

Operating system:

[0029] An operating system is shown in fig. 1. A controller 1 reads a combustion gas temperature by means of a sensor 3 of combustion gas temperature, and the operation of an intake air damper 2 is controlled by means of a multiphase algorithm for controlling air flow into a hearth. Further, the system, by means of a sensor 4 of water jacket temperature, measures the temperature of water jacket circulation and controls the operation of a circulation pump 5 of the central heating circulation.

Algorithm for Controlling the Combustion Process:

[0030] During its start-up, the controller 1 checks the value of combustion gas temperature ($T_{\text{combustion gas}}$) and, by means of the algorithm illustrated in fig. 2, it decides which operation mode to select.

[0031] The operation algorithm has access to an internal programmed table with fireplace parameters which contain individual characteristics of a given hearth. Before starting to operate, directly after installation of the device, the user selects the type of hearth being used. The algorithm reads a list of parameters and further operation of the algorithm is carried out with the participation of individualised characteristics of the hearth. Exemplary individualised characteristics considered herein are: minimum and maximum temperature of automatic operation, alarm temperature, control set for automatic operation, firing up temperature and others.

[0032] The operation algorithm is divided into two main operation modes, an automatic operating mode being further divided into operation mode phases:

1. firing up;
2. automatic:
 - a. phase I;
 - b. phase II;
 - c. phase III;
 - d. phase IV.

1. Firing up.

[0033] It aims at effective firing up of a wood volume which is located in the hearth. For this purpose, the temperature in the hearth is increased to the predetermined

value of firing up temperature ($T_{\text{firing up}}$), illustrated in Fig. 4, which results in a large opening of the intake air damper 2.

[0034] Control of an executive module, which is the intake air damper 2 herein, is performed on the basis of proportional-integral-differentiation from the feedback of the combustion gas temperature signal.

[0035] After exceeding the predetermined value of automatic operation temperature ($T_{\text{automatic operation}}$), the controller 1 will count the prolongation time of firing up ($t_{\text{firing up}}$). After this time, the controller 1 will switch to automatic operation mode phase I.

2. Operation Mode: Automatic

[0036] It takes place directly after firing up operation mode. Switching takes place at the moment when the prolongation time of firing up ($t_{\text{firing up}}$) reaches the end. Opening values of the intake air damper 2 on the border of firing up and automatic modes and phases I, II and III are respectively passed between operation modes and phases so that rapid opening and closing of the intake air damper 2 on the borders of modes do not take place.

a. Automatic Operation Mode - Phase I

[0037] It aims at bringing the combustion gas temperature ($T_{\text{combustion gas}}$) from firing up operation mode to automatic one phase II. In this phase, a very slow closing of the intake air damper 2 takes place in order to bring the combustion gas temperature to the predetermined value of automatic operation temperature ($T_{\text{automatic operation}}$) which is illustrated in Fig. 4. The slow closing of the intake air damper 2 is based on an integrating algorithm which closes the intake air damper 2 the faster, the further the value of combustion gas temperature ($T_{\text{combustion gas}}$) is from the predetermined temperature of automatic operation ($T_{\text{automatic operation}}$).

b. Automatic Operation Mode - Phase II

[0038] When combustion gas temperature ($T_{\text{combustion gas}}$) in phase I becomes equal to the predetermined value of automatic operation temperature ($T_{\text{automatic operation}}$), the algorithm switches the automatic operation mode to phase II. It is a substantial operating phase of the automatic mode. It aims at maintaining combustion gas temperature constant, acting with the intake air damper 2 on the amount of air supplied to the hearth.

[0039] Control of the damper 2 is performed on the basis of proportional-integral-differentiation from the feedback of the combustion gas temperature signal.

[0040] The predetermined combustion gas temperature ($T_{\text{combustion gas}}$), being input to the algorithm for automatic operation, is determined as an average temperature, for a given fireplace, obtained during testing validation of the fireplace.

c. Automatic Operation Mode - Phase III

[0041] The temperature of transition to automatic operation phase III is not constant. The moment of transition to automatic operation phase I depends strictly on the detection of fuel shortage, as described below, in section entitled "Fuel Shortage". In order for the algorithm to switch phase II to phase III, the same conditions as in detection of fuel shortage have to be met. Therefore, switching to phase III of the automatic operation algorithm depends strictly on the first occurrence of fuel prompt. This occurs when combustion gas temperature ($T_{\text{combustion gas}}$) falls from automatic operation temperature ($T_{\text{automatic operation}}$) to the predetermined value, denoted as operation temperature ($T_{\text{operation}}$), illustrated in fig. 4, this decrease having to be maintained in time (monotonicity) and to occur quickly enough (see conditions indicated in section "Fuel Shortage").

[0042] In this phase, the intake air damper 2 is controlled in so-called positive feedback, limiting the air supplied to the hearth together with the decrease of combustion gas temperature ($T_{\text{combustion gas}}$). It results in limiting the amount of oxygen supplied to the hearth in the last phase of wood combustion and limiting the emission of harmful substances into the atmosphere.

[0043] Re-transmission to automatic operation mode phase II occurs when the value of combustion gas temperature ($T_{\text{combustion gas}}$) starts to increase (angle of inclination of temperature curve in relation to horizontal axis, i.e. time axis, is positive).

d. Automatic Operation Mode - Phase IV

[0044] When combustion gas temperature ($T_{\text{combustion gas}}$) falls below the predetermined value of operation temperature ($T_{\text{operation}}$), the algorithm closes the intake air damper 2 to the hearth and performs periodic airings of the hearth.

[0045] In this phase, afterburning of the hearth occurs. The controller 1 performs cyclical blowthroughs in the hearth in order to check whether fuel was added to the hearth. If the fuel was added and combustion gas temperature ($T_{\text{combustion gas}}$) exceeds the predetermined value of operation temperature ($T_{\text{operation}}$), the controller 1 will pass to operation in automatic mode phase II described in section 2b. The number of blowthroughs, their duration and waiting time are programmed. After an unsuccessful reincrease in the value of combustion gas temperature ($T_{\text{combustion gas}}$) above the predetermined value of operation temperature ($T_{\text{operation}}$), on completion of the series of blowthroughs, the algorithm passes to STOP mode which is the completion of the process.

Fuel Shortage

[0046] The algorithm detects ending fuel in the fireplace chamber. The algorithm for fuel shortage detection is based on the observation of the curve of combustion

gas temperature ($T_{\text{combustion gas}}$) as a function of time.

[0047] When the following conditions are fulfilled:

1) combustion gas temperature ($T_{\text{combustion gas}}$) is lower in relation to the predetermined value of automatic operation temperature ($T_{\text{automatic operation}}$) by the value of $dT_{\text{fuel shortage}}$ (fig. 6);

2) the intake air damper 2 was opened, and further opening does not bring change in the decrease of combustion gas temperature ($T_{\text{combustion gas}}$);

3) combustion gas temperature ($T_{\text{combustion gas}}$) maintains a constant decreasing trend within 30 seconds;

4) decreasing rate (angle of inclination) of combustion gas temperature ($T_{\text{combustion gas}}$) is not lower than the predetermined value of *Det. of fuel shrtg min* (Fig. 5);

5) decreasing rate (angle of inclination) of combustion gas temperature ($T_{\text{combustion gas}}$) is not higher than the predetermined value of *Det. of fuel shrtg max* (Fig. 5);

then the algorithm will report the need to add fuel to the hearth (fuel prompt will occur).

Algorithm for Controlling the Water Circulation

[0048] The water circulation is controlled autonomously to the circulation process of fuel combustion in the hearth. The operation of water circulation is based on the measurement of water jacket temperature (T_{jacket}), illustrated in fig. 7, with the use of the sensor 4 of water jacket temperature.

[0049] The operation of water jacket circulation depends strictly on minimum water jacket temperature ($T_{\text{water jacket}}$), beyond which the water jacket is incorporated in the operation by means of the circulation pump 5 of the central heating circulation (Fig. 7). The number of heat receivers may vary depending on the application (for example an operating boiler 8) or instantaneous demand for heat in the heating system 11 (for example a heating circuit exchanger 10 in operation), or preparation of domestic hot water. Depending on the number of receivers, appropriate additional pumps (6, 7) are installed.

Interaction of Algorithms

3. The Operation of Water Jacket Circulation Pumps during Particular Operation Phases of the Algorithm for Controlling the Air Flow into the Heart

[0050] Depending on the active operation mode, the operation of pumps 5, 6, 7 is performed in different ways.

a. Operation of Pumps in Firing up Mode

[0051] In the firing up operation mode, which is described in detail in section 1 above, the pumps 5, 6, 7 are authorised to operate when the fired up hearth heats water in the water jacket to minimum temperature ($T_{\text{jacket operation}}$). If, in the central heating system, there is not any demand for heat, the operation of pumps 5, 6, 7 cannot be started. The algorithm for the operation of pumps 5, 6, 7 monitors the maximum water jacket temperature so as not to cause its overheating i.e. water in the jacket exceeding the predetermined value ($T_{\text{jacket operation max}}$) and, if necessary, starts the stopped pumps 5, 6, 7 despite the lack of demand for heat. Below the minimum water jacket temperature, the operation of pumps 5, 6, 7 is always stopped, regardless of demand for heat from the heating system circuit.

b. Operation of Pumps in Automatic Modes of Phases I, II, III

[0052] In automatic operation modes of phases I, II or III, which are described in detail in sections 2a, 2b and 2c, respectively, the control of pump operation is the same as in the above described firing up mode (section 3a).

c. Operation of Pumps in Automatic Mode of Phase IV

[0053] In automatic operation mode of phase IV which is described in detail in section 2d, operation of pumps is stopped so as not to lead to reverse cooling of the system through the afterburning of the hearth. The algorithm monitors water jacket temperature and, in the event of its overheating, it allows the heat receivers to run periodically.

Alarm Situations

[0054] The algorithm detects that thresholds of maximum combustion gas and water jacket temperatures are exceeded and, on this basis, takes appropriate alarm actions.

[0055] Exceeding the maximum temperature of water in the jacket results in a complete cut off of the air flow to the hearth chamber and in starting of all possible heat reception sources (8, 10, 11).

[0056] Exceeding the maximum combustion gas temperature results in a complete cut off of the air flow to the hearth chamber.

Claims

1. A multiphase method for controlling an air flow into the hearth of a fireplace for solid fuels, especially wood, within a system comprising the said fireplace with the hearth, an intake air damper (2), a sensor

(3) of combustion gas temperature, a water jacket connected to a heating circuit through at least one pump (5, 6, 7), a sensor (4) of water temperature in the water jacket and a controller (1), connected at least with the sensor (3) of combustion gas temperature, with the sensor (4) of water temperature in the water jacket, with the intake air damper (2) and with at least one pump (5, 6, 7), **characterised in that**, by means of the sensor (3) of combustion gas temperature, temperature of combustion gases ($T_{\text{combustion gas}}$) produced as a result of solid fuel combustion in the fireplace hearth is measured, and depending on this temperature, the air flow to the hearth is controlled as follows:

a) [firing up phase] the intake air damper (2) is opened, resulting in substantial flow of air into the hearth, and then the opening of the damper (2) is controlled on the basis of proportional-integral-differentiation from the feedback of the combustion gas temperature signal until the measured combustion gas temperature ($T_{\text{combustion gas}}$) exceeds the predetermined value of firing up temperature ($T_{\text{firing up}}$), followed by

b) [automatic mode, phase I] the intake air damper (2) is gradually and slowly closed in order to bring the observed combustion gas temperature ($T_{\text{combustion gas}}$) to the predetermined value of automatic operation temperature ($T_{\text{automatic operation}}$) based on an integrating algorithm which closes the intake air damper (2) the faster, the further the value of combustion gas temperature ($T_{\text{combustion gas}}$) is from the predetermined temperature of automatic operation ($T_{\text{automatic operation}}$), followed by

c) [automatic mode, phase II] combustion gas temperature ($T_{\text{combustion gas}}$) is maintained constant, changing the opening of the intake air damper (2), the control of the intake air damper (2) being performed on the basis of proportional-integral-differentiation from the feedback of the combustion gas temperature signal, and simultaneously

d) [detection of fuel shortage] combustion gas temperature ($T_{\text{combustion gas}}$) is monitored and, in the controller (1), a prompt of fuel shortage is generated when the following conditions are simultaneously fulfilled:

- the observed combustion gas temperature ($T_{\text{combustion gas}}$) is lower in relation to the predetermined automatic operation temperature ($T_{\text{automatic operation}}$) by the value of $dT_{\text{fuel shortage}}$;
- the intake air damper (2) remains opened, and the combustion gas temperature

- ($T_{\text{combustion gas}}$) decreases in time;
- combustion gas temperature ($T_{\text{combustion gas}}$) maintains a constant decreasing trend within 30 seconds;
 - decreasing rate of combustion gas temperature ($T_{\text{combustion gas}}$) in time is not lower than the predetermined value of *Det. of fuel shrtg min*;
 - decreasing rate of combustion gas temperature ($T_{\text{combustion gas}}$) in time is not higher than the predetermined value of *Det. of fuel shrtg max*;
- e) [automatic mode, phase III] the intake air damper (2) is controlled in a positive feedback, gradually closing the intake air damper (2) together with a decrease in combustion gas temperature ($T_{\text{combustion gas}}$), and if the observed combustion gas temperature ($T_{\text{combustion gas}}$) starts to increase in time - a transition to phase c) [automatic mode, phase II] takes place,
- f) [automatic mode, phase IV] from a few to several hearth blowthroughs are performed by a complete opening of the intake air damper (2) in order to check whether fuel was added to the hearth; if fuel was added and the observed combustion gas temperature ($T_{\text{combustion gas}}$) exceeds the predetermined value of operation temperature ($T_{\text{operation}}$), then a transition to phase c) [automatic mode, phase II] takes place; if fuel was not added and the observed combustion gas temperature ($T_{\text{combustion gas}}$), on completion of the blowthrough series, does not exceed the predetermined value of operation temperature ($T_{\text{operation}}$), then the process is completed.
2. The method according to claim 1, **characterised in that**, in addition, the water heating circuit is controlled based on water jacket temperature (T_{jacket}) measured by the sensor (4) of water temperature in water jacket, autonomously to controlling the air flow into the hearth.
 3. The method according to claim 2, **characterised in that**, at least one circulation pump of the central water heating circulation is attached only in the case if the water jacket temperature (T_{jacket}) exceeds the predetermined minimum value ($T_{\text{jacket operation}}$).
 4. The method according to claim 2 or 3, **characterised in that**, at least one circulation pump of the central water heating circulation is attached always in the case if the water jacket temperature (T_{jacket}) exceeds the predetermined maximum value ($T_{\text{jacket operation max}}$).
 5. The method according to claim 2, 3 or 4, **character-**
- ised in that**, at least one circulation pump of the central water heating circulation is turned off always in the case if automatic mode phase IV for controlling the air flow into the hearth takes place.
6. The method according to any one of the preceding claims, **characterised in that**, the value of firing up temperature parameter ($T_{\text{firing up}}$) ranges from 300 °C to 600 °C, more preferably from 400 °C to 500 °C, and most preferably from 450 °C to 500 °C.
 7. The method according to any one of the preceding claims, **characterised in that**, the value of automatic operation temperature parameter ($T_{\text{automatic operation}}$) ranges from 150 °C to 500 °C, more preferably from 200 °C to 400 °C, and most preferably from 250 °C to 350 °C.
 8. The method according to any one of the preceding claims, **characterised in that**, the value of operation temperature parameter ($T_{\text{operation}}$) ranges from 80 °C to 255 °C, more preferably from 120 °C to 180 °C, and most preferably from 150 °C to 180 °C.
 9. The method according to any one of the preceding claims, **characterised in that**, the value of $dT_{\text{fuel shortage}}$ parameter ranges from 10 °C to 60 °C, more preferably from 15 °C to 50 °C, and most preferably from 20 °C to 40 °C.
 10. The method according to any one of the preceding claims, **characterised in that**, the value of *Det. fuel shrtg min* parameter ranges from 1 to 30, more preferably from 1 to 20, and most preferably from 1 to 5.
 11. The method according to any one of the preceding claims, **characterised in that**, the value of *Det. fuel shrtg max* parameter ranges from 1 to 60, more preferably from 5 to 60, and most preferably from 20 to 60.
 12. The method according to any one of the preceding claims, **characterised in that**, the value of minimum water jacket temperature parameter ($T_{\text{jacket operation}}$) ranges from 20 °C to 60 °C, more preferably from 40 °C to 50 °C, and most preferably from 40 °C to 50 °C.
 13. The method according to any one of the preceding claims, **characterised in that**, the value of maximum water jacket temperature parameter ($T_{\text{jacket operation max}}$) ranges from 70 °C to 99 °C, more preferably from 80 °C to 95 °C, and most preferably from 89 °C to 91 °C.
 14. The method according to any one of the preceding claims, **characterised in that**, the predetermined combustion gas temperature, being input to the al-

gorithm, is determined as an average fireplace temperature from fireplace tests.

15. The method according to any one of the preceding claims, **characterised in that**, the controller (1) has access to a fireplace parameter database which contains individual characteristics of a given hearth and a value of at least one of the parameters: $T_{\text{firing up}}$, $T_{\text{automatic operation}}$, $T_{\text{operation}}$, $dT_{\text{fuel shortage}}$, *Det. of fuel Shrtg min*, *Det. of fuel shrtg max*, $T_{\text{jacket operation}}$, $T_{\text{jacket operation max}}$, is read from this database.

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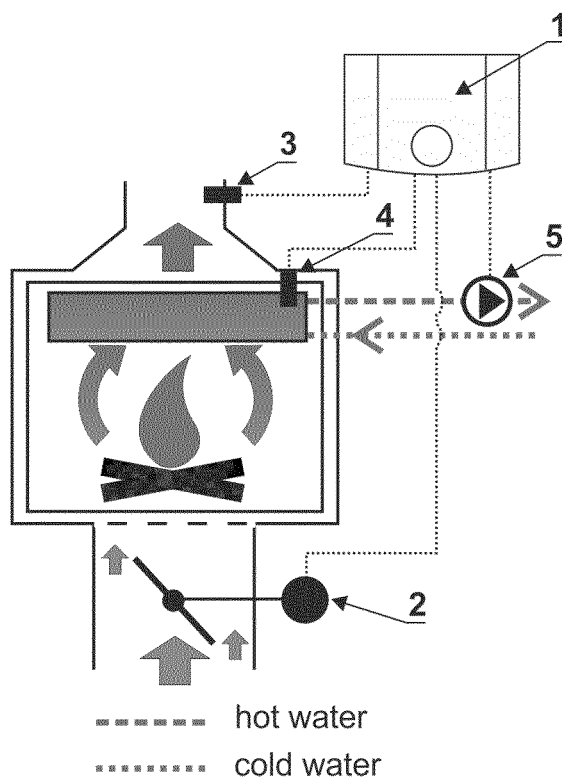


Fig. 1

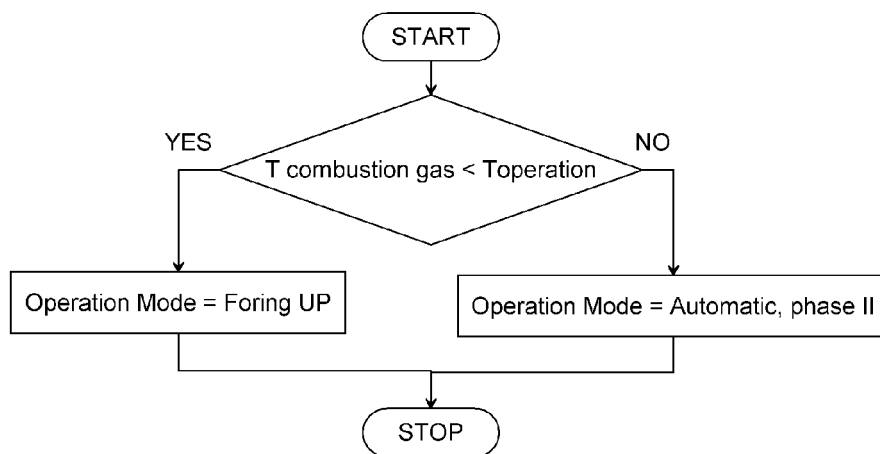


Fig. 2

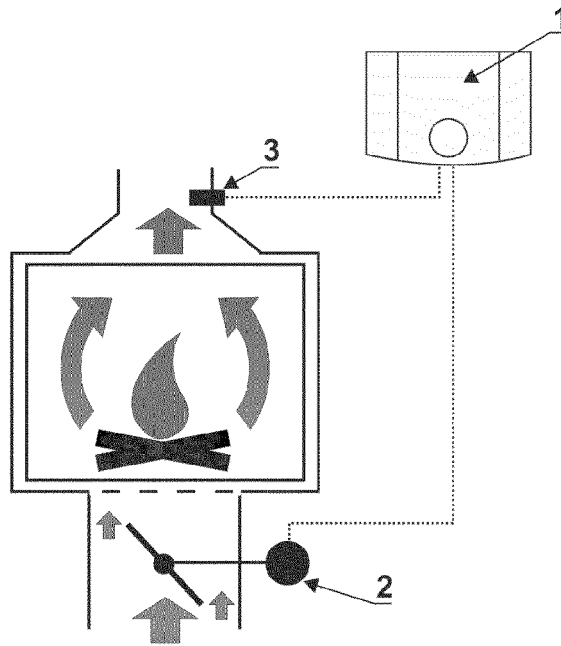


Fig.3

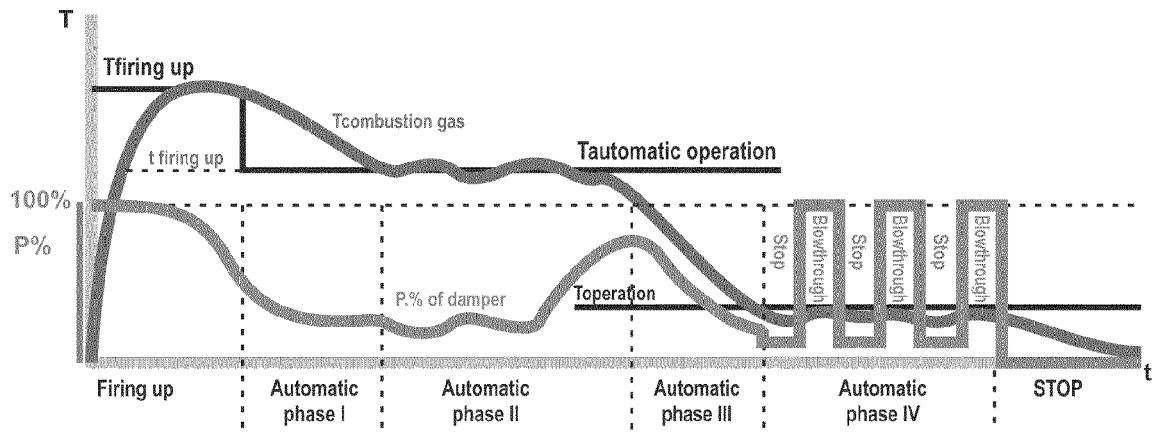


Fig.4

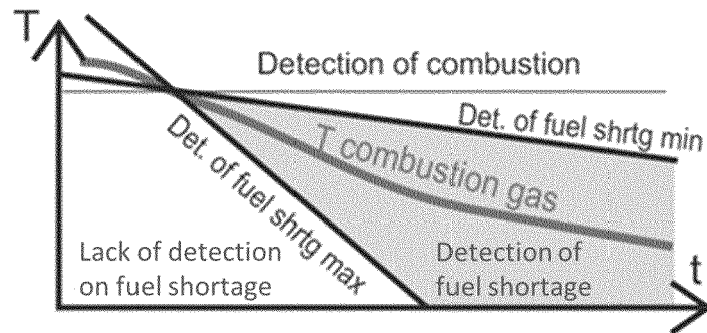


Fig. 5

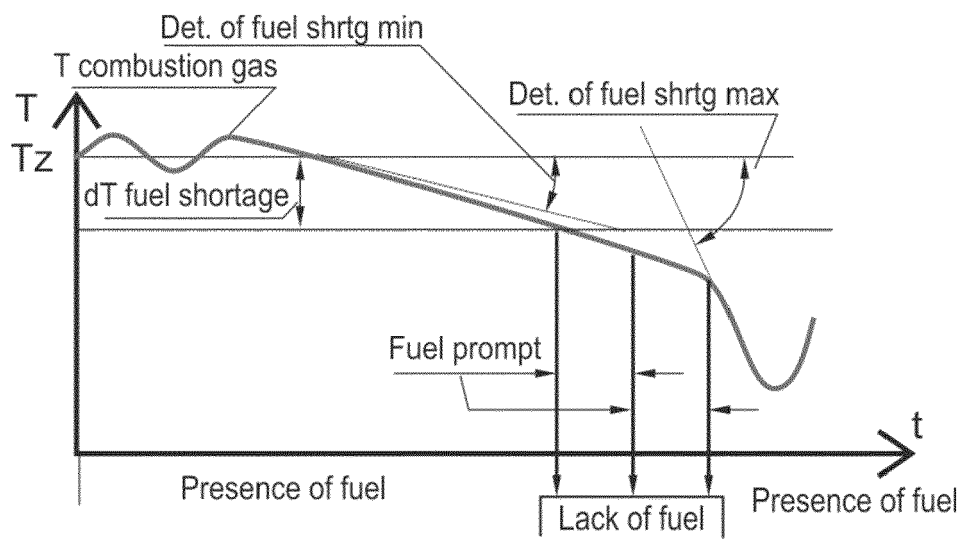


Fig. 6

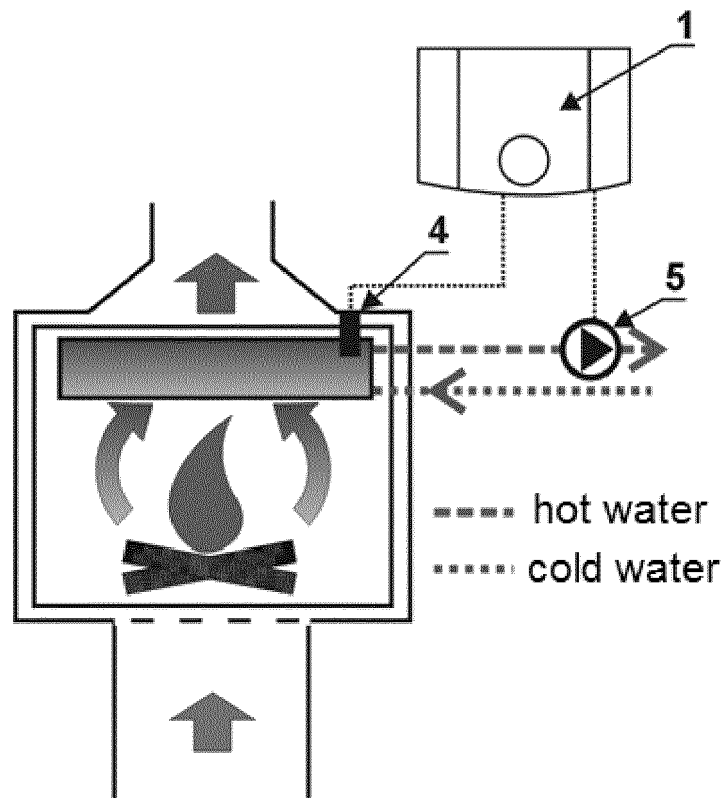


Fig. 7

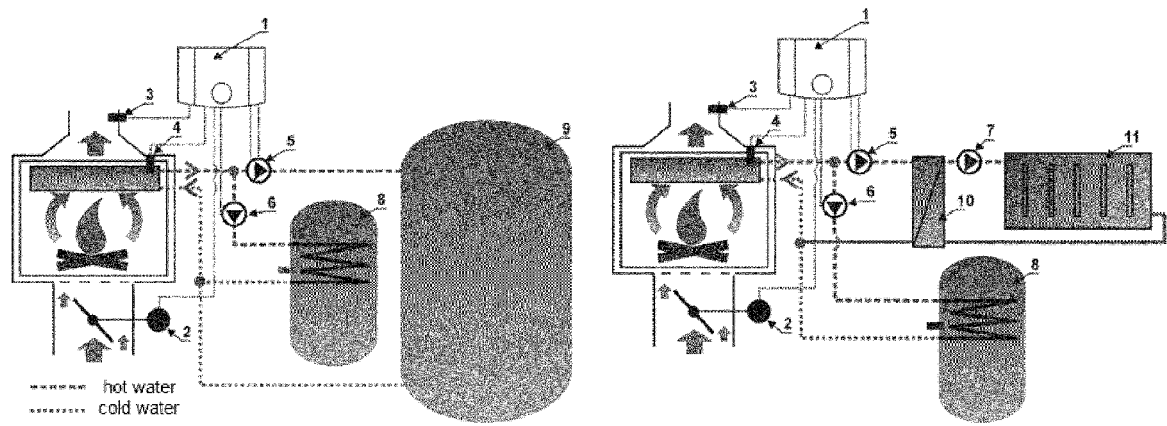


Fig. 8



EUROPEAN SEARCH REPORT

Application Number
EP 14 46 1505

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A	DE 10 2009 054621 A1 (EBERSPAECHER J GMBH & CO [DE]) 16 June 2011 (2011-06-16) * the whole document *	1-15	
A	EP 2 626 637 A1 (TULIKIVI OYJ [FI]) 14 August 2013 (2013-08-14) * abstract *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F24B F23N
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 8 July 2014	Examiner Munteh, Louis
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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08-07-2014

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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