(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 980 789 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
15.10.2008 Bulletin 2008/42

(51) Int Cl.:
F23N 5/00 *(2006.01)*

(21) Application number: **08005249.1**

(22) Date of filing: **20.03.2008**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(30) Priority: **12.04.2007 IT pc20070023**

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(54) **Method for monitoring and regulating the combustion of a gas boiler, and boiler for the embodiment of said method**

(57) A method of monitoring the combustion of a gas boiler, which includes:
• determination of an interval within which the concentration of the various products of combustion present in the combustion gases can vary;
• measurement of the CO value in the combustion gases and simultaneous measurement of CO_2, O_2 or both;
• regulation of the ratio of the air/gas mixture supplied to the burner, on the basis of the data detected,

wherein the data detected relating to the concentration of products of combustion in the combustion gases are compared with the data contained in a table stored in the boiler control system which states the maximum and minimum values allowed for each product of combustion, so that combustion is optimised.

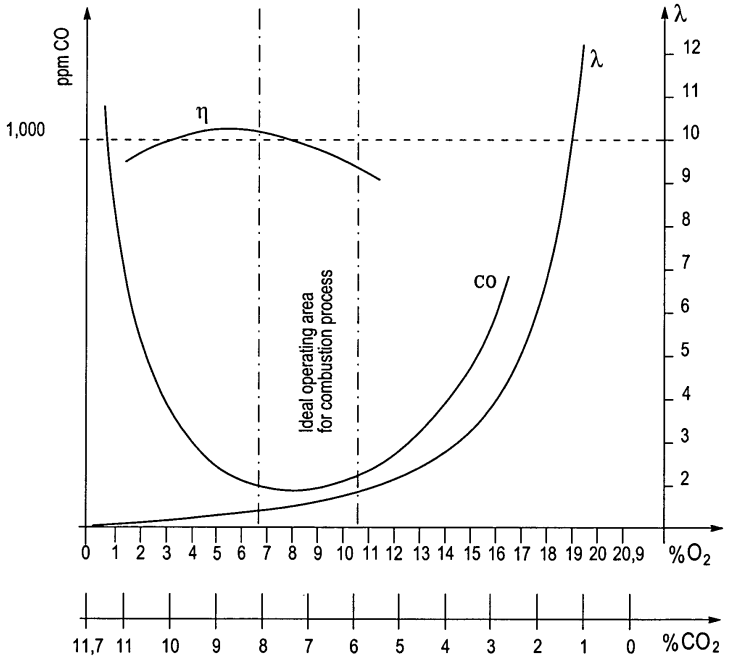

Fig. 2

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Description

[0001] This invention relates to a method of monitoring and regulating the combustion of a gas boiler, which involves determining an interval within which the concentration of the various products of combustion present in the combustion gases of a specific boiler can vary, said concentration corresponding to a situation of optimum efficiency in measuring the quantity of CO in the combustion gases and simultaneously measuring the quantity of O_2, and regulating the ratio of the air/gas mixture supplied to the burner on the basis of the values detected so as to maximise its efficiency, the concentration of said products of combustion being maintained within a predetermined interval in said condition.

[0002] Basically, a feedback-driven dynamic control of the combustion conditions is introduced so that the air/gas ratio can be adjusted to ensure continuous regulation of the boiler in the event of variation of the environmental conditions, and variations in the boiler characteristics over time.

[0003] The invention also relates to a gas boiler characterised in that it includes means designed to measure the quantity of CO and at least one other product of combustion such as CO_2 or O_2 in the combustion gases, and means designed to vary the ratio of the air/gas mixture supplied to the burner on the basis of the values detected, so as to maintain them within a pre-determined interval.

[0004] The efficient operation of a boiler depends mainly on the characteristics of the air-fuel mixture supplied to the burner, which affects not only the efficiency of the boiler but also the quantity of products of combustion present in the exhaust gases, and consequently the healthiness of the environment.

[0005] Until a few years ago, boilers were regulated by initial adjustment of the air/gas ratio, without any subsequent monitoring of the combustion characteristics.

[0006] Products of combustion, especially CO, CO_2 and O_2, are formed in exhaust gases as a result of combustion. The quantity of said products varies according to the combustion characteristics, which in turn depend on the characteristics of the mixture, the boiler, and the environment in which it operates.

[0007] The problem that arises for one skilled in the art is therefore to maximise the efficiency of a boiler and consequently ensure low emission of said products of combustion.

[0008] However, the percentage of products of combustion present in the exhaust gases is not directly proportional to the flow rate or the air/gas ratio, but with the variation of the flow rate it varies according to curves that differ considerably from one component to another, depending on the environmental conditions in which the boiler operates, the characteristics of the boiler and so on.

[0009] It is therefore impossible to identify a priori an optimum regulation which can be maintained in all operating conditions and throughout the life cycle of a boiler, and the initial regulation of the air/gas ratio is insufficient to ensure optimum combustion over time.

[0010] If an excessively rich mixture (excess of gas) is conveyed to the burner, in addition to the lower efficiency of the boiler uncombusted products will be formed, especially carbon monoxide, which is very harmful, whereas combustion with a lean mixture (excess of air) leads to reduced efficiency due to the significant loss of heat in the fumes, together with a considerable increase in the production of carbon monoxide and a reduction in CO_2.

[0011] It is therefore obviously important for the correct air/gas ratio to be maintained in the combustion mixture under all conditions and throughout the life cycle of the boiler. However, this problem is difficult to solve, because the air/gas ratio required to provide optimum operation varies with the flow rate of the fuel mixture and with time, as wear on the boiler causes the various hydraulic, mechanical and electronic components involved in combustion, such as the burner, fan, heat exchanger, etc. to deteriorate, and this causes a deterioration in boiler performance and different operating conditions, which leads to an increase in emissions of products of combustion.

[0012] According to the state of the art, boilers are known in which a sensor measures the quantity of a product of combustion, in particular carbon dioxide, present in the exhaust gases, and this parameter is used to regulate the air/gas mixture.

[0013] However, this system does not allow all parameters to be monitored in order to provide optimum boiler regulation which takes account not only of efficiency but also of the presence of toxic products in the combustion gases, so that the safety of the installation can also be monitored.

[0014] Said problem is now solved by the present invention, which provides a boiler management method and a boiler for the embodiment of said method wherein, for a specific type of boiler, the quantity of products of combustion present in the exhaust gases is determined experimentally on the basis of the air/gas ratio, a graph is constructed, and the pattern of the curves is used to determine a range of air/gas ratio values wherein said products of combustion are present to a lesser extent and the efficiency of the boiler is acceptable; said value range is taken as comparison parameter; the percentage of said products of combustion present in the boiler exhaust gases is then determined continuously, and checked to ensure that this quantity falls within the experimentally determined value range, the proportion of the air/gas mixture being adjusted when said values fall outside said interval.

[0015] Basically, the ratio of the air/gas mixture is continually adjusted on the basis of the actual state of combustion, to obtain a dynamic feedback-driven control of combustion which allows the performance of a boiler to be maintained unchanged over time in terms of efficiency, consumption and emissions, thus ensuring greater safety and maintaining correct operation and satisfactory efficiency of the boiler, unchanged over time.

[0016] This invention will now be described in detail, by way of example but not of limitation, by reference to the annexed figures wherein:

- figure 1 schematically illustrates a boiler according to the invention;
- figure 2 is a graph showing the quantity of products of combustion present in the combustion gases as a function of the air/gas ratio;
- figures 3 and 4 are block diagrams illustrating the management of a boiler with the method according to the invention.

[0017] As shown in figure 1, no. 1 indicates a boiler burner associated with a heat exchanger 2. The burner is supplied with gas through a pipe 3 fitted with a valve 4 with modulator, while the air in combustion chamber 5 is supplied by a fan 6 with modulator.

[0018] An electronic control unit of known type 7 controls the modulator of fan 6 and the modulator of valve 4.

[0019] Exhaust gas outlet pipe 8 is fitted with a pair of sensors 9 and 10.

[0020] The first sensor measures the quantity of carbon monoxide in the exhaust fumes, while the second measures the quantity of O_2, CO_2 or both.

[0021] The data detected by sensors 9 and 10 is sent to control unit 7.

[0022] A table is stored in control unit 7 in which the different fuel mixture flow rate values are associated with the minimum and maximum values of the products of combustion which may be present in the exhaust gases during optimum operation of the boiler.

[0023] Said minimum and maximum value range can be determined experimentally for each type of boiler.

[0024] In particular, the conditions of greatest efficiency will be determined by laboratory tests, during which the emissions are also measured.

[0025] See the graph in figure 2, for example.

[0026] Here, curve λ represents the function $\lambda = 20.95 / (20.95 - k)$, where k is the percentage of O_2 in the exhaust gases, and η represents the efficiency.

[0027] The aim is to strike a compromise between the conditions of greatest efficiency and the conditions of lowest CO emissions.

[0028] The optimum regulation of the boiler will therefore correspond to the area of lowest CO emissions, with a certain tolerance.

[0029] These tolerances are defined by the values of CO_2 and O_2.

[0030] The efficiency of the boiler will increase with a higher CO_2 value (corresponding to a lower quantity of O_2), but so will the CO emissions. The increase in CO will be considered acceptable up to a maximum level allowed by the local legislation or directives (GAD).

[0031] A reduction in the CO_2 level (corresponding to a greater quantity of O_2) will lead to lower efficiency.

[0032] Once again, the CO emissions will increase due to the excess of air in the mixture.

[0033] By means of the CO and CO_2 (and/or O_2) sensors, the boiler control systems can measure and modify the efficiency of the boiler on the basis of the emissions measured in the exhaust gas flow.

[0034] An electronic control unit of known type (in which the predefined CO, O_2 and CO_2 parameters are stored) will maintain combustion under the ideal conditions, regardless of external disturbing factors such as variations in gas quality, wind, boiler installation altitude, air temperature, or flow resistance in the gas flow.

[0035] Depending on requirements, the electronic control unit will supply and regulate the speed of the air suction fan and the modulation of the gas regulation valve, according to the level of the emissions measured by the CO and CO_2 (and/or O_2) sensors.

[0036] When said interval has been determined, the maximum and minimum values for each product of combustion will be stored in control unit 7.

[0037] During the operation of the boiler, the values measured by sensors 9 and 10 will be input into the control unit, which compares them with the stored values.

[0038] If the quantity of products of combustion detected differs from those for which combustion is considered ideal, the control unit will activate the modulator of valve 4 to vary the quantity of gas in the mixture, or alternatively will regulate the motor of fan 6 until sensors 9 and 10 detect values which are correct or do not differ greatly form the optimum values.

[0039] If the values detected differ excessively from the stored value, an alarm system with a boiler shutdown device may be activated.

[0040] In the event of a variation in the characteristics of the gas (e.g. the heat value), the boiler will self-regulate on that basis to ensure that combustion is always ideal.

[0041] The boiler management method is illustrated schematically in the graphs in figures 3 and 4.

[0042] The boiler management electronics perform a first-level regulation on the basis of the required heating power, by controlling the current supplied to the gas valve modulator and/or the rotation speed of the air fan as well as the water output temperature, as schematically illustrated in figure 3.

[0043] Simultaneously, the control logic constantly analyses combustion, to regulate the air/gas ratio so as to maintain the emissions within the pre-determined range, as schematically illustrated in the diagram in figure 4.

[0044] Depending on the values detected by sensors 9 and 10, the control logic will operate, preferably by varying the quantity of air first, so as not to destabilise the system in terms of heating performance, and adjusting the gas flow rate if the air flow rate is close to the allowed limit.

[0045] Basically, the method according to the invention provides feedback-driven control of the safety regulation of a boiler based on continual analysis of the actual state of combustion, thus providing considerable advantages (i) in terms of regulation, because the determination of

the quantity of air and gas to be sent to the burner not only depends on the heating performance requirement, but is also determined on the basis of the actual state of combustion, and (ii) in terms of reliability, because in addition to the traditional tests, the emissions are checked directly and constantly.

[0046] This improves efficiency, optimises consumption over time, reduces emissions of products of combustion during the life of the boiler and is thus more environment-friendly, and allows system autodiagnosis.

Claims

1. Method of monitoring the combustion of a gas boiler, which said method is **characterised in that** it includes:

   • determination of an interval within which the concentration of the various products of combustion present in the combustion gases can vary;
   • measurement of the CO value in the combustion gases and simultaneous measurement of CO_2, O_2 or both;
   • regulation of the ratio of the air/gas mixture supplied to the burner, on the basis of the data detected.

2. Method as claimed in claim 1, wherein the data detected relating to the concentration of products of combustion in the combustion gases are compared with the data contained in a table stored in the boiler control system which states the maximum and minimum values allowed for each product of combustion, so that combustion is optimised.

3. Method as claimed in claim 2, wherein CO and CO_2 are measured simultaneously.

4. Method as claimed in claim 2, wherein CO and O_2 are measured simultaneously.

5. Method as claimed in claim 1, wherein:

   • the quantity of products of combustion present in the exhaust gases is determined on the basis of the air/gas ratio;
   • a range of air/gas ratio values is determined wherein the quantity of CO is minimal and the efficiency of the boiler is acceptable, said interval being defined on the basis of O_2 and/or CO_2 values considered acceptable;
   • said value interval is used as comparison parameter;
   • the percentage of said products of combustion present in the boiler exhaust gases is then determined continuously, and checked to ensure that this quantity falls within the determined value range, the proportion of the air/gas mixture being adjusted when said values fall outside said interval.

6. Boiler with combustion control systems for the embodiment of the method claimed in any of claims 1 to 4, **characterised in that** it includes:

   • means designed to measure the CO concentration present in the combustion gases;
   • means designed to measure the concentration of CO_2, O_2 or both in the combustion gases;
   • means designed to vary the ratio of the air/gas mixture supplied to the burner according to the values detected.

7. Boiler as claimed in claim 6, **characterised in that** it includes a control unit designed to control a gas supply valve with modulator and/or an air supply fan with modulator on the basis of the concentration of products of combustion in the combustion gases.

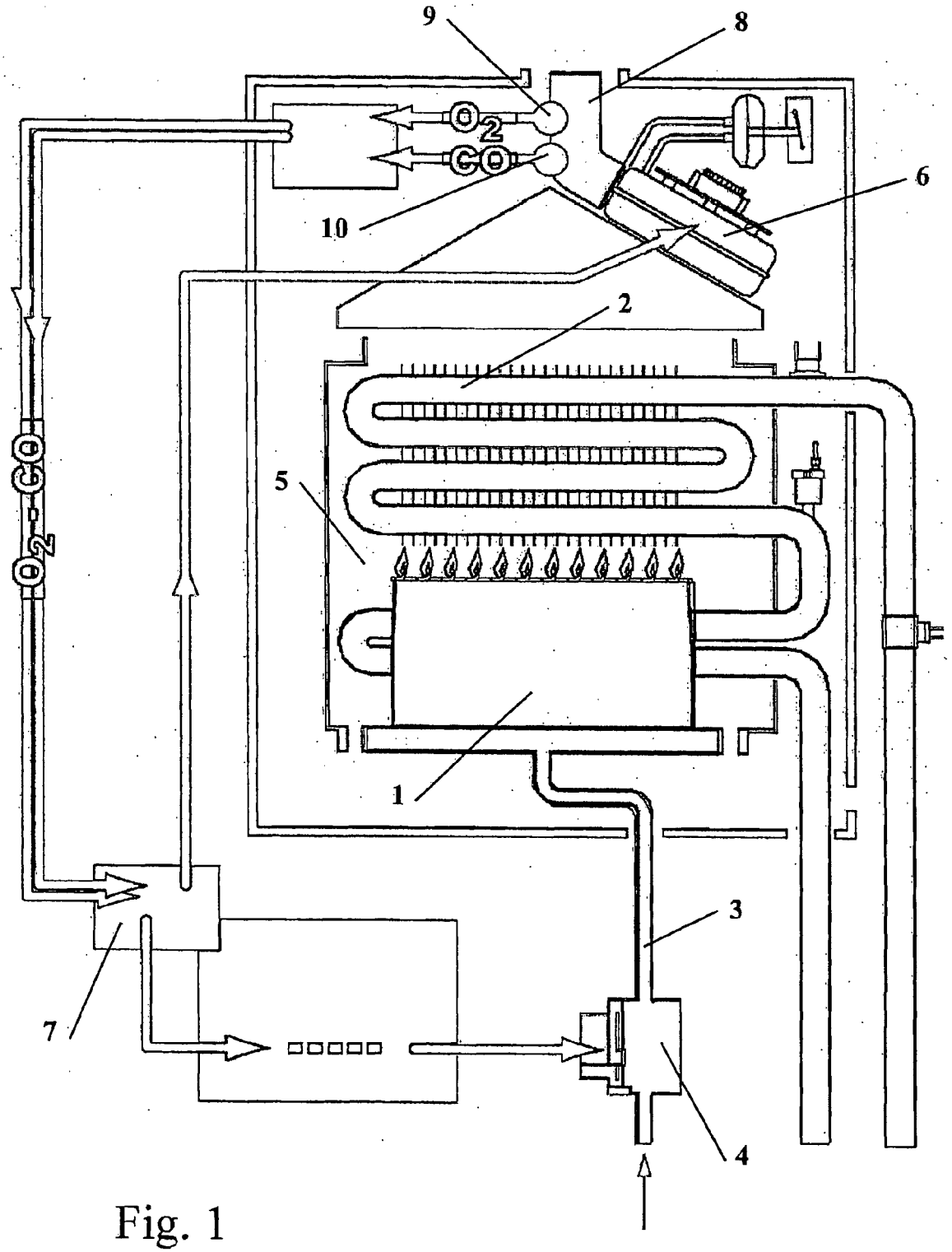

Fig. 1

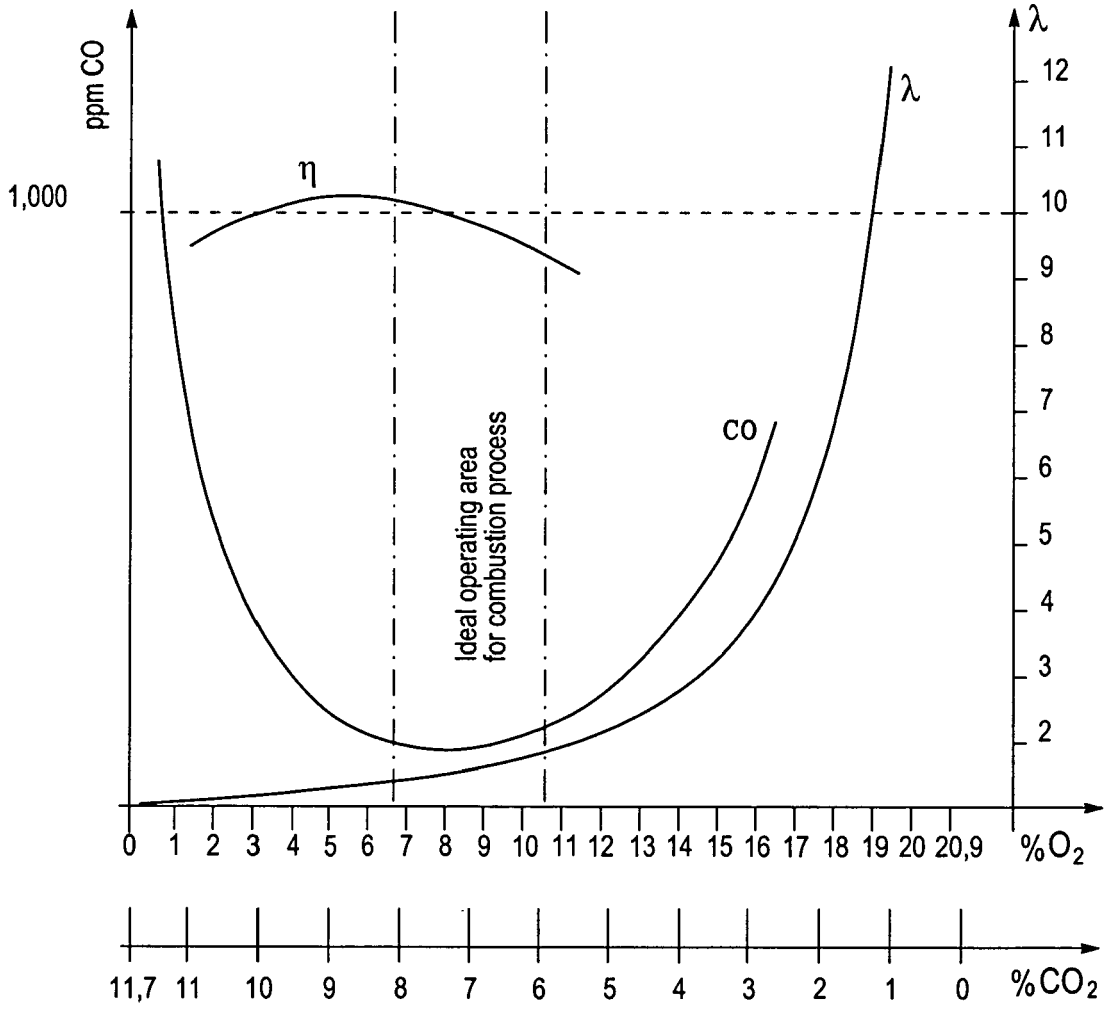
ppm CO
1,000
η
λ
CO
Ideal operating area
for combustion process
λ
12
11
10
9
8
7
6
5
4
3
2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 20,9
%O2
11,7 11 10 9 8 7 6 5 4 3 2 1 0
%CO2

Fig. 2

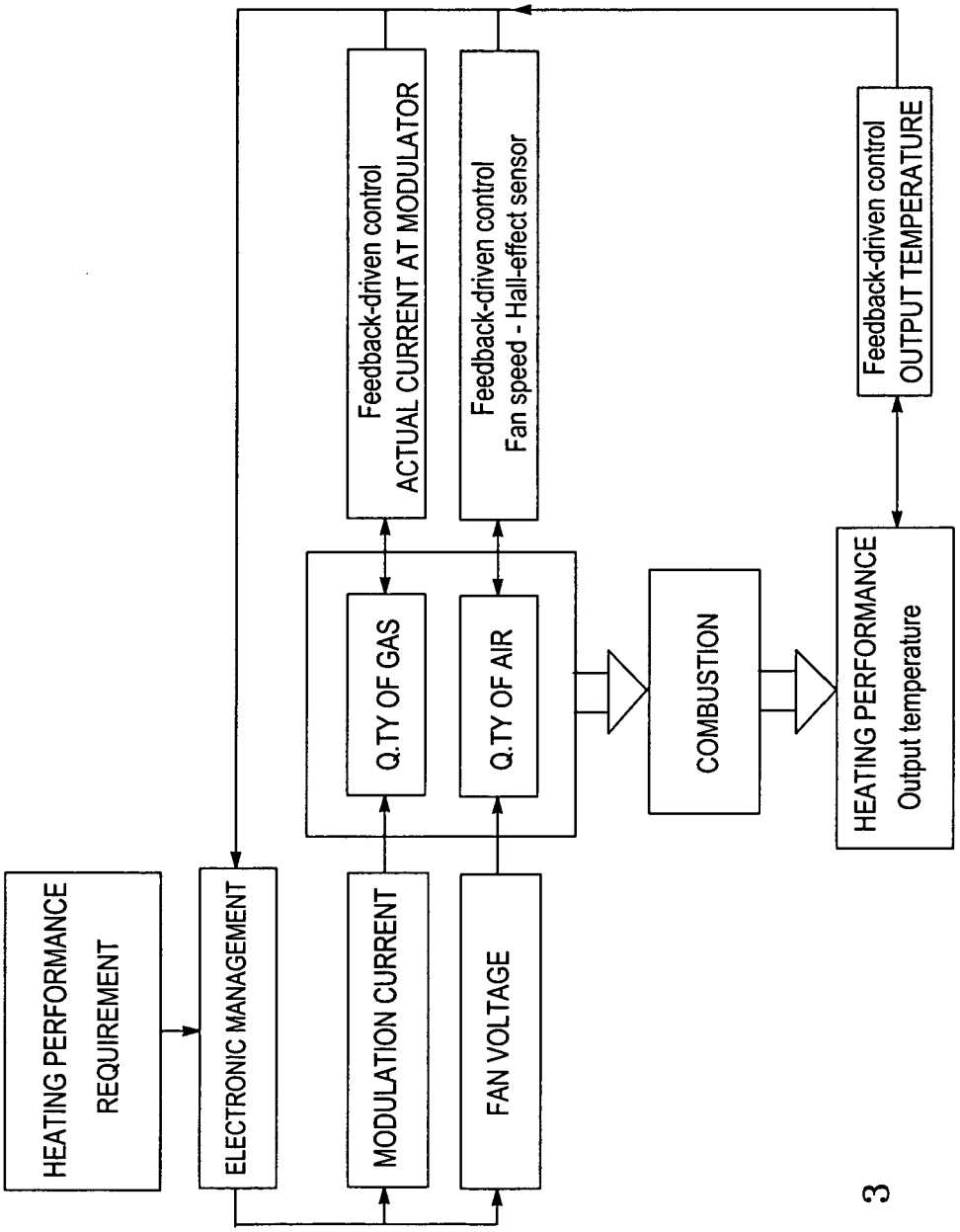
HEATING PERFORMANCE
REQUIREMENT
ELECTRONIC MANAGEMENT
MODULATION CURRENT
FAN VOLTAGE
Q.TY OF GAS
Q.TY OF AIR
Feedback-driven control
ACTUAL CURRENT AT MODULATOR
Feedback-driven control
Fan speed - Hall-effect sensor
COMBUSTION
HEATING PERFORMANCE
Output temperature
Feedback-driven control
OUTPUT TEMPERATURE

Fig. 3

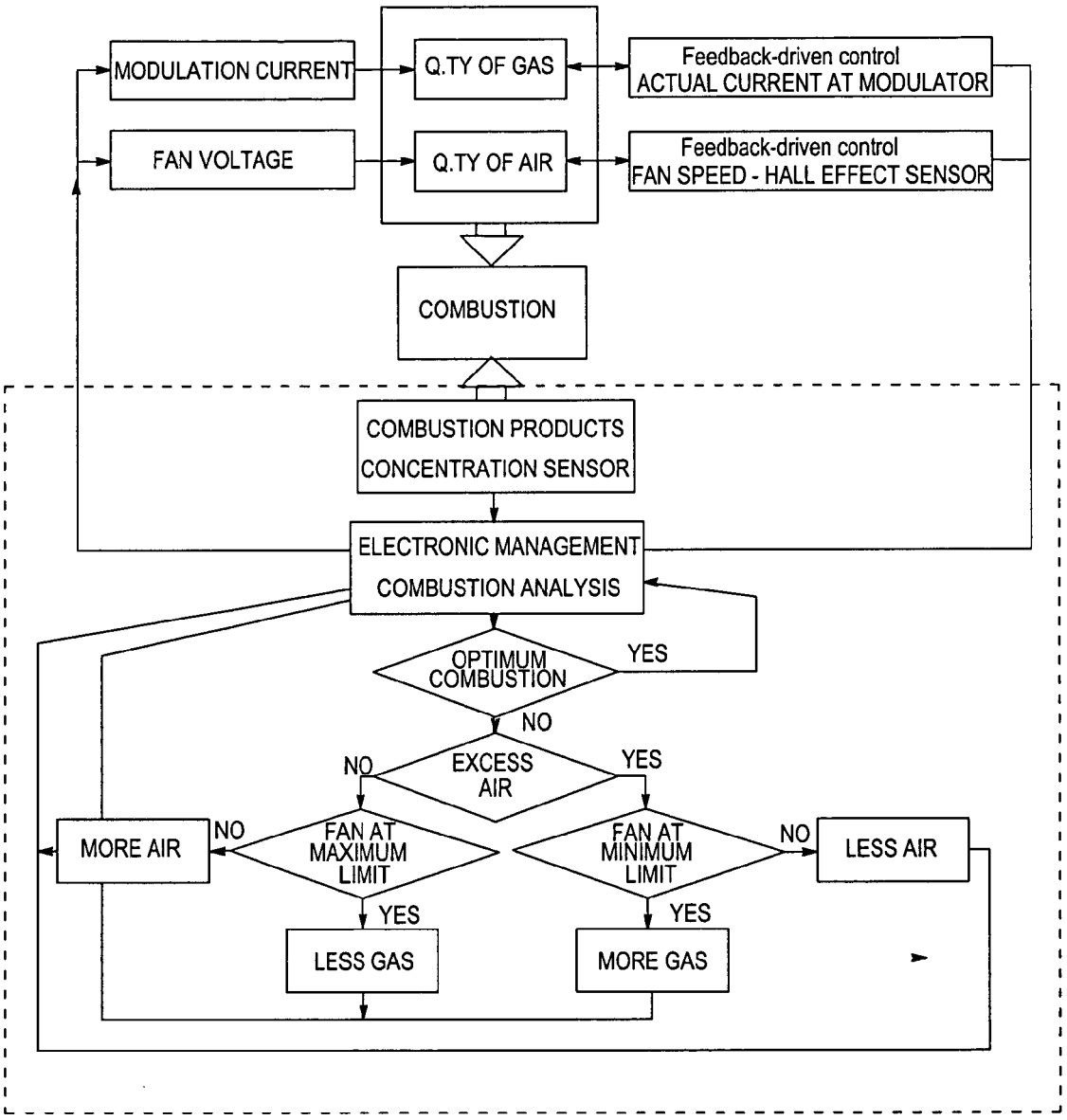
MODULATION CURRENT
Q.TY OF GAS
Feedback-driven control
ACTUAL CURRENT AT MODULATOR
FAN VOLTAGE
Q.TY OF AIR
Feedback-driven control
FAN SPEED - HALL EFFECT SENSOR
COMBUSTION
COMBUSTION PRODUCTS
CONCENTRATION SENSOR
ELECTRONIC MANAGEMENT
COMBUSTION ANALYSIS
OPTIMUM
COMBUSTION
YES
NO
NO
EXCESS
AIR
YES
MORE AIR
NO
FAN AT
MAXIMUM
LIMIT
FAN AT
MINIMUM
LIMIT
NO
LESS AIR
YES
YES
LESS GAS
MORE GAS

Fig. 4