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

(11) Publication number: **0 075 369**
A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **82201152.4**

(51) Int. Cl.³: **F 23 N 5/00**

(22) Date of filing: **17.09.82**

(30) Priority: **18.09.81 NL 8104308**

(43) Date of publication of application: **30.03.83**
Bulletin 83/13

(84) Designated Contracting States: **AT BE CH DE FR GB IT LI LU NL SE**

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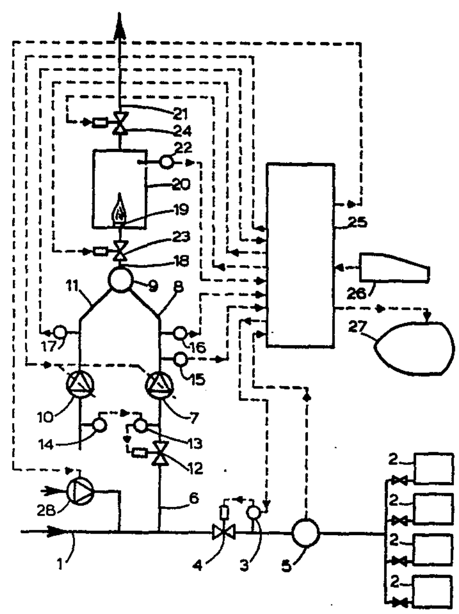
(54) Method and device for keeping the heat load on gas-fired equipment constant.

(57) Method and apparatus for keeping constant the heat load on gas-fired equipment connected to a gas distribution grid which supplies a gas of variable composition. The pressure of the gas supplied is controlled in such a way, that the square root of the pressure difference between the ambient air and the gas, multiplied by the Wobbe-index of the gas supplied, has a constant value. The Wobbe-index is determined by burning a volume-controlled sample flow of the gas with a volume-controlled excess flow of combustion air and measuring the oxygen content of the combustion gases. This oxygen content has a linear correlation to the Wobbe-index if the fuel gas consists mainly of lower hydrocarbons, as is the case with natural gas. Also, the density of the gas supplied is measured and from the density and the oxygen content measured both the Wobbe-index W as well as the gross colorific value H of the gas are calculated. From the momentary values of H and the gas volume consumed the consumption of heat energy by the gas-fired equipment can be determined, e.g. as a basis for financial settlement.



EP 0 075 369 A1

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METHOD AND DEVICE FOR KEEPING THE HEAT LOAD ON GAS-FIRED EQUIPMENT CONSTANT

The invention relates to a method of keeping the heat load on gas-fired equipment connected to a gas distribution grid constant by withdrawing a volume-controlled sample stream from the fuel gas supplied completely combusting the flow of sample gas in a combustion chamber with a volume-controlled excess flow of combustion air, measuring the oxygen content of the combustion gases and, on the basis of the oxygen content measured, controlling a property of the gas in such a manner as to keep said heat load substantially constant.

The heat load (hereinafter to be referred to as simply 'load') of gas-fired equipment is understood to be the amount of gas, by volume, burnt per unit of time (reduced to normalized pressure and temperature), multiplied by the calorific value of the gas. For good and safe operation of gas equipment it is necessary that the effective load corresponds to the design load.

The load on a gas-fired installation is determined by the following relation:

$$Q = C_1 \; H \sqrt{\frac{\Delta p}{d}} \qquad (1)$$

If

$$W = \frac{H}{\sqrt{d}} \qquad (2)$$

then

$$Q = C_1 \; W \; \sqrt{\Delta p} \qquad (3)$$

where:

Q = the load on the gas-fired installation;

C_1 = a constant determined by the dimensions of the feed nozzle of the gas-fired installation;

H = the gross calorific value of the fuel gas;

d = the relative density of the fuel gas with respect to air;

Δp = the pressure drop across the feed nozzle of the gas-fired installation; this is usually equal to the difference in pressure between the gas supplied and the ambient air;

W = the Wobbe index of the fuel gas.

The Wobbe index is an important quantity in combustion engineering. According to formula (3), when the gas pressure is constant, the load on gas-fired equipment is constant if the Wobbe index of the fuel gas is constant, even if the composition of the fuel gas is variable.

A method as described in the preamble is known from Dutch Patent Application No. 7808476 by Applicant, laid open for public inspection. The property of the gas which is controlled in the known method is the Wobbe index. In said method, use is made of the fact that, under suitably chosen measuring conditions, there is a good correlation between the measured oxygen content in the combustion gases from the combustion chamber and the Wobbe index of the fuel gas, if the combustible part of said gas consists of lower hydrocarbons, as is the case with natural gas. In this known method, a fuel gas of substantially constant Wobbe index is obtained by mixing gases of different origin and composition; the ratio in which the gases are mixed is controlled in such a manner that the measured oxygen content is constant. If then, besides the Wobbe index, also the gas pressure is constant, the heat load on the connected gas-fired equipment is constant.

The known method has the drawback that it cannot be used when mixing various suitable gases is impossible, for example because only one fuel gas with varying heating characteristics is available. The object of the invention is to provide a method which does not have this drawback.

The method according to the invention is characterized in that the pressure of the gas fed to the equipment is controlled in such a way that the following relation is at all times substantially met:

$$\sqrt{(P_g - P_1)} \cdot W = D,$$

where:

P_g = the above-mentioned gas pressure, which is to be controlled;

P_1 = the pressure of the ambient air;

W = the Wobbe index of the gas, to be calculated from the oxygen content measured;

D = a preselected contant value.

As follows from equation (3) above, the load on the connected gas-fired equipment is then constant, even if the Wobbe index of the fuel gas varies.

Preferably, also the density of the supplied gas relative to air is measured, and from the oxygen content measured and the relative density measured the Wobbe index W as well as the calorific value H is determined; the relation is given by equation (2) above. If in addition the volume of gas consumed is measured, from the outcome of the summation, over time, of the momentary values of the product of the volume of gas consumed per unit of time and the calorific value the amount of heat energy supplied with the gas can be determined. When gas of variable quality is supplied, it is not the number of cubic metres of gas supplied but the heat energy supplied in the form of that gas that is to be charged.

When the measuring data is to be used not only for checking and control purposes, but also for financial settlement, it is desirable to carry out the measurement more accurately than is possible with the method described in the aboven-mentioned Dutch Patent Application No. 7808476. In that case, the volume-controlled flows of gas and combustion air are preferably fed to the combustion chamber by means of two volumetric pumps operating synchronously, for example positive-displacement pumps, the pressure of the sample gas fed to the sample-gas pump being controlled such as to equal the pressure of the air supplied to the combustion-air pump.

In the determination of W and H from the oxygen content of the combustion gases, also the oxygen content of the air supplied is introduced into the calculation. Usually, this can be assumed to be the oxygen content of the ambient air (20.95 %). However, if the oxygen content of the combustion air may vary, this content is preferably measured. If the sample gas may have an oxygen content of some significance, e.g. more than 1.5 per cent by volume, this too is preferably measured; the value for the oxygen content in air is then increased by a correction factor calculated from the oxygen content in the gas.

The background of the invention is as follows:

From the oxygen contents measured, the excess coefficient in the combustion chamber during combustion is inferred:

$$n = \frac{L}{L_{min}} \quad (4)$$

from the relation

$$n = 1 + \frac{[O_2]_z \cdot C_2}{[O_2]_a - [O_2]_z} \quad (5)$$

where:

n = the excess coefficient

L = the amount of combustion air, by volume, supplied per unit of time;

L_{min} = the minimum amount of air, by volume, required for stoichiometric combustion of the amount of gas G;

G = the amount of sample gas, by volume, supplied per unit of time;

$[O_2]_z$ = the oxygen content of the combustion gases;

$[O_2]_a$ = the corrected oxygen content of the combustion air;

C_2 = an empirical constant.

The corrected oxygen content $[O_2]_a$ is calculated by:

$$[O_2]_a = [O_2]_1 + G/L\ [O_2]_g \quad (6)$$

where:

$[O_2]_1$ = the oxygen content of the combustion air;

$[O_2]_g$ = the oxygen content of the sample gas.

(All oxygen contents in per cent by volume).

Empirically, the following proves to be a very good approximation of reality:

$$H = C_3 \cdot \frac{L}{G} \cdot \frac{1}{n} \quad (7)$$

where C_3 is another empirical constant.

The calorific value H and the Wobbe index W can thus be determined from the oxygen contents measured, the relative gas density d and the air and gas flows L and G, according to equations (5), (7) and (2).

It is noted that the empirical constants C_2 and C_3 are really virtually constant only for fuel gases whose combustible part consists of lower hydrocarbons, so that the formulas (5) and (7) also hold for these gases only.

The measurements can be carried out continuously as well as periodically. In the latter case, the flows of gas and air are fed to the combustion chamber periodically. After an equilibrium has established itself, the supply of gas and air and the discharge of combustion gases are blocked. After the gas mixture confined in the combustion chamber has been combusted completely, the oxygen content of the combustion gases is measured. The gas consumption of the device itself is thus limited; the frequency at which the measurements are repeated is chosen in dependence on the rate at which the properties of the gas change.

The invention relates also to a device for the realization of the method according to the invention for keeping the heat load of gas-fired equipment connected to a gas distribution grid constant, which device is provided with a combustion chamber, means to withdraw a volume-controlled sample flow from the fuel gas supplied and to feed this sample to the combustion chamber, means to add a volume-controlled flow of combustion air to the sample flow, means in the combustion chamber to enable complete combustion of the gas-air mixture, an oxygen meter to measure the oxygen content of the combustion gases and means to control a property of the gas in such a manner that said heat load is kept substantially constant.

According to the invention, the device is provided with a pressure-controlling device for controlling the pressure of the gas supplied to the gas-fired equipment and with calculating means which from the oxygen content measured can calculate a setting signal and feed it to the pressure controlling device, such that at all times the following equation is substantially met:

$$\sqrt{(P_g - P_1)} \cdot W = D$$

where:

P_g = the pressure of the gas controlled by the pressure-controlling device

P_1 = the pressure of the ambient air;

W = the Wobbe index of the gas;

D = a preselected constant value.

The connected gas-fired equipment may be gas-fired equipment with a combustion chamber as well as open gas-fired equipment, such as cooking apparatus.

Preferably, the means to add the volume-cotrolled flow of combustion air to the sample flow comprise a first volumetric pump and the means to withdraw a sample stream from the fuel gas supplied comprise a second volumetric pump in synchronous action with the first volumetric pump and a pressure-controlling device which can control the pressure of the gas fed to the second pump in such a manner that this pressure equals the pressure of the combustion air fed to the first pump. The pumps may be any suitable type of volumetric pump, for example positive-displacement pumps.

When it is to be expected that the device will be used for fuel gases with an oxygen content of some significance, for example more than 1.5 per cent by volume, the device is preferably provided with an oxygen meter in order to measure this oxygen content in the flow of sample gas and feed a measuring signal to said calculating means. If the oxygen content of the combustion air may vary, the device is preferably also provided with an oxygen meter to measure this oxygen content as well and provide said calculating means with a measuring signal.

The device is preferably provided with a density meter for measuring the density relative to air of the sample gas which can feed a measuring signal to said calculating means. From the oxygen contents measured and the density, the calculating means can calculate the Wobbe index and the calorific value of the gas.

The invention is explained with reference to the drawing, in which a schema showing the principle of a device according to the invention is represented by way of non-restricting example.

Through gas supply conduit 1 a fuel gas, for example natural gas, is supplied to a number of gas-fired equipment items 2 (for example a battery of gas-fired industrial furnaces) whose load is to be kept constant. The pressure of the gas supplied to the gas-fired equipment items 2 is controlled by a pressure-controlling device 3, which controls a reducing valve 4; the consumed volume of gas is measured with a gas meter 5.

From the gas supplied, a sample flow is withdrawn through a sample conduit 6 with the aid of a volumetric positive-displacement pump 7, which feeds the sample gas to a mixing chamber 9 through a conduit 8. With the aid of a volumetric positive-displacement pump 10, a flow of combustion air is fed to the mixing chamber 9 through a conduit 11. In the sample conduit 6 a reducing valve 12 is incorporated which is controlled by a pressure-controlling device 13 which controls the pressure of the gas fed to pump 7 in such a way that this pressure equals the pressure of the combustion air fed to pump 10; to this end, the pressure-controlling device 13 receives a setting signal from the pressure meter 14 which measures the pressure of the air supplied to pump 10. The positive-displacement pumps 7 an 10 run synchronously, so that the ratio between the volumes of gas and air fed to the mixing chamber 9 is constant; in dependence on the average gas composition to be expected, the air volume: gas volume ratio is set at a value of between, for example, 11 and 16.

The density relative to air of the gas flowing through conduit 8 can be measured with a gas density meter 15; the oxygen content of this gas can be measured with an oxygen meter 16 and the oxygen content of the combustion air flowing through conduit 11 can be measured with an oxygen meter 17.

From the mixing chamber 9, the gas-air mixture obtained is supplied to a burner 19 in a combustion chamber 20 through a conduit 18. The burner 19 is provided with an electric ignition (not shown). The combustion gases can be discharged through a discharge conduit 21. The oxygen content of the combustion gases can be measured with an oxygen meter 22. Conduits 18 and 21 can be closed with shut-off valves 23 and 24 respectively.

The measuring data from the density meter 15, the oxygen meters 16, 17 and 22 and the gas meter 5 are fed to a microprocessor calculating unit 25, which from the measuring data generates numerical values for the calorific value and the Wobbe index of the gas supplied to the gas-fired equipment items 2 and for the amounts of gas heat energy consumed. These numerical values can be shown on a display 27. In addition, the calculating unit 25 generates a signal for the pressure setting of the pressure-controlling device 3, in such a way that the load on the gas-fired equipment 2 remains constant, as discussed above. On a keyboard 26, the commands for controlling the complete installation can be given.

Further, the schema indicates the possibility to supply a correcting gas through conduit 28, controlled by calculating unit 25. This may for example be desirable if the pressure to be set at pressure-controlling device 3 moves outside the desired control range, which might happen when the Wobbe index of the gas is temporarily considerably higher than it is on average. The pressure to be set might then become so low that the gas-fired equipment items 2 would no longer function reliably. By addition of a low-calorific or inert gas (e.g. air), the Wobbe index can then be lowered. Conversely, the Wobbe index can be raised by addition of a high-calorific gas, if it is too low.

The device according to the schema can be operated not only continuously but also discontinuously. Pumps 7 and 10 are then taken into operation periodically, after valves 23 and 24 have been opened. After and equilibrium has estabilished itself, valves 23 and 24 are closed and pumps 7 and 10 are stopped. In this case the oxygen meter 22 is preferably provided with an electrochemical oxygen sensor (a so-called zirconium oxide sensor) with operates at high temperatures (approx. 800 °C), ensuring complete combustion of the gas mixture confined in the combustion chamber 20; the oxygen measurement takes place when this complete combustion has taken place.

Obviously, the oxygen meter 16 must not be a meter operating at high temperatures, because at a high temperature any oxygen present in the fuel gas would react with the combustible components. Another type of oxygen meter should be used, for example a meter based on the paramagnetic properties of oxygen. If the oxygen content to be expected is negligible, the oxygen meter 16 will be dispensed with.

CLAIMS

1. Method of keeping the heat load on gas-fired equipment connected to a gas distribution grid constant by withdrawing a volume-controlled sample flow from the fuel gas supplied, completely combusting the flow of sample gas in combustion chamber with a volume-controlled excess flow of combustion air, measuring the oxygen content of the combustion gases and on the basis of the measured oxygen content controlling a property of the gas in such a manner as to keep said heat load substantially constant, the method being characterized in that the pressure of the gas fed to the gas-fired equipment is controlled in such a manner that at all times the following relation is substantially met:

$$\sqrt{(P_g - P_1)} \cdot W = D$$

where:

P_g = the above mentioned gas pressure, which is to be controlled;

P_1 = the pressure of the ambient air;

W = the Wobbe index of the gas, which is to be calculated from the oxygen content measured;

D = a preselected constant value.

2. Method according to claim 1, characterized in that also the density relative to air of the gas supplied is measured and that from the oxygen content measured and the relative density measured the Wobbe index W as well as the gross calorific value H of the gas are calculated.

3. Method according to claim 2, characterized in that also the volume of gas consumed is measured, and that the consumption of heat energy supplied with the gas is determined by summation, over time, of the momentary values of the product of the gas volume consumed per unit of time and the calorific value.

4. Method according to any one of the claims 1-3 characterized in that the volume-controlled flows of sample gas and combustion air are fed to the combustion chamber by means of two volumetric pumps operating synchronously, the pressure of the sample gas fed to the pump for the sample gas being controlled in such a manner that it equals the pressure of the air fed to the pump for combustion air.

5. Method according to any one of the claims 1-4, characterized in that the oxygen content of the combustion air supplied is measured and the value found is introduced into the calculation of W and/or H from the oxygen content of the combustion gases.

6. Method according to any one of the claims 1-5, characterized in that the oxygen content of the sample gas is measured and the value found is introduced into the calculation of W and/or H from the oxygen content of the combustion gases.

7. Device for the realization of the method according to any one of the claims 1-6 for keeping the heat load on gas-fired equipment connected to a gas distribution grid constant, which device is provided with a combustion chamber, means to withdraw a volume-controlled sample flow from the fuel gas supplied and feed this sample flow to the combustion chamber, means to add a volume-controlled flow of combustion air to the sample flow, means in the combustion chamber to enable complete combustion of the gas-air mixture, an oxygen meter for measuring the oxygen content of the combustion gases and means to control a property of the gas in such a manner that said heat load is kept substantially constant, characterized in that the device is provided with a pressure-controlling device for controlling the pressure of the gas fed to the gas-fired equipment and with calculating means which from the oxygen content can calculate a setting signal and feed it to the pressure-controlling device such that at any time the following relation is substantially met:

$$\sqrt{(P_g - P_1)} \cdot W = D$$

where:

P_g = the pressure of the gas which is controlled by the pressure-controlling device;

P_1 = the pressure of the ambient air;

W = the Wobbe index of the gas;

D = a preselected constant value.

8. Device according to claim 7, characterized in that the means to add a volume-controlled flow of combustion air to the sample flow substantially comprise a first volumetric pump and the means to withdraw a volume-controlled sample flow from the fuel gas supplied substantially comprise a second volumetric pump in synchronous action with the first volumetric pump and a pressure-controlling

device which can control the pressure of the gas fed to this second pump in such a manner that this pressure equals the pressure of the combustion air fed to the first pump.

9. Device according to claim 7 or 8, characterized by an oxygen meter for measuring the oxygen content of the flow of sample gas which can feed a measuring signal to said calculating means.

10. Device according to any one of the claims 7-9, characterized by an oxygen meter for measuring the oxygen content of the combustion air supplied which can feed a measuring signal to said calculating means.

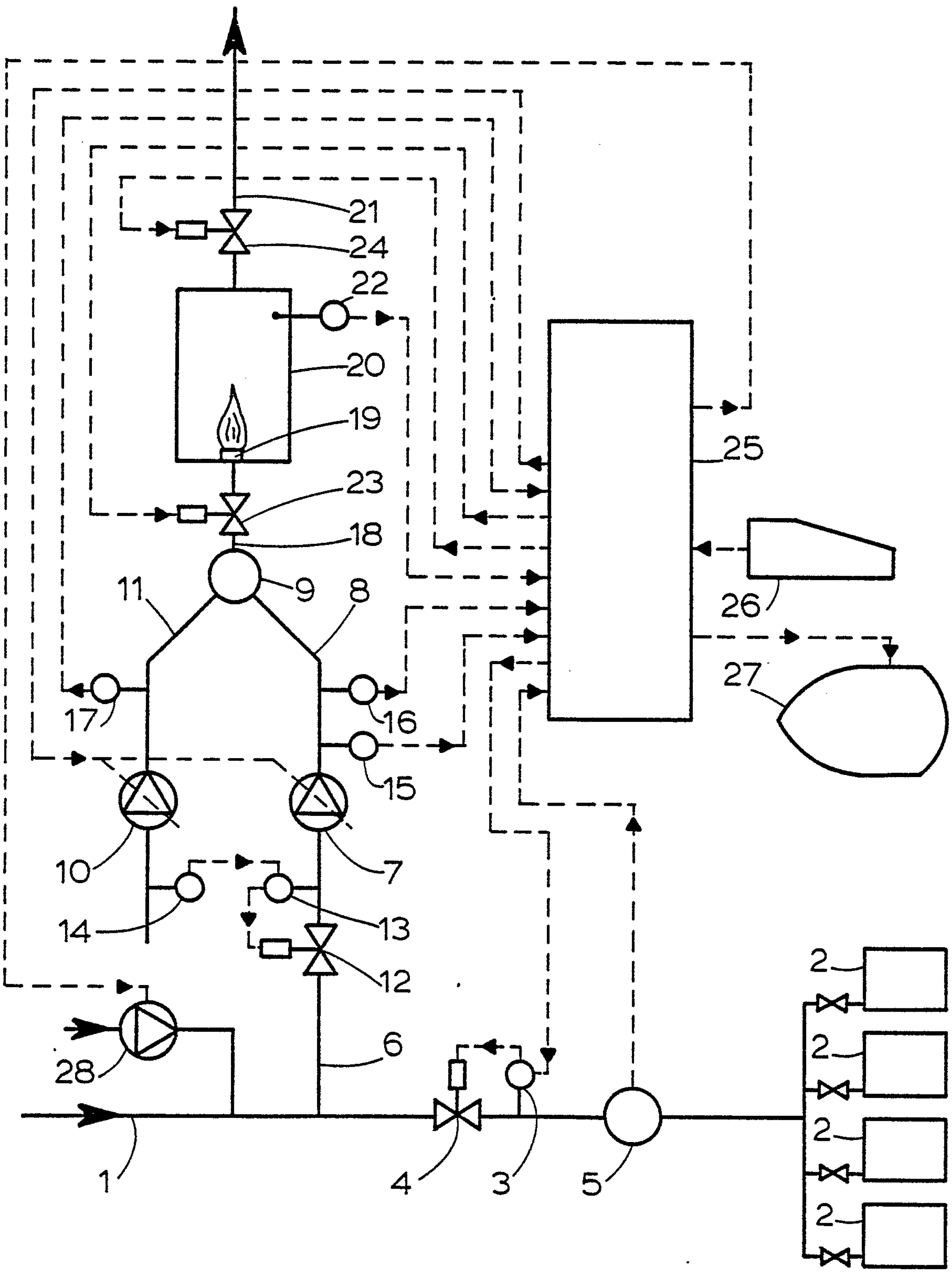
11. Device according to any one of the claims 7-10, characterized by a density meter for measuring the density relative to air of the sample gas which can feed a measuring signal to said calculating means.

12. Device according to any one of the claims 7-11, characterized by a volumetric gas meter for measuring the consumption of gas by volume which can feed a measuring signal to said calculating means.

13. Device according to any one of the claims 7-12, characterized by two valves in respectively the feed and discharge of the combustion chamber, which valves can be opened and closed periodically by control signals from the calculating unit in order to periodically confine a sample of combustion gases in the combustion chamber and measure the oxygen content thereof.

14. Method as described and explained with reference to the drawing.

15. Device as described and explained with reference to the drawing.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EUROPEAN SEARCH REPORT

Application number

EP 82 20 1152

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
E	GB-A-2 080 512 (SNAM S.P.A.) *Figures 1-3; abstract*	1,7	F 23 N 5/00
A	GB-A-2 036 290 (R.S.LANARY) *Figures 1-3; abstract*	1,7	
A	GB-A-1 565 310 (BATELLE DEVELOPMENT CORP.) *Figure 1; claims 1-6*	1,7	
A	DE-B-1 016 884 (KERAM INDUSTRIES BEDARFS K.G.) *Figures; column 4, lines 60-65*	1,4,7, 8	
A	US-A-2 829 954 (W.H.DAILEY Jr. et al.)		TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			F 23 N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	09-12-1982	THIBO F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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