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

(11) Publication number: 0 191 353
A1

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: 86101087.4

(22) Date of filing: 28.01.86

(51) Int. Cl.⁴: F 23 N 1/02

(30) Priority: 01.02.85 FI 850427

(43) Date of publication of application: 20.08.86
Bulletin 86/34

(84) Designated Contracting States: AT DE FR GB IT SE

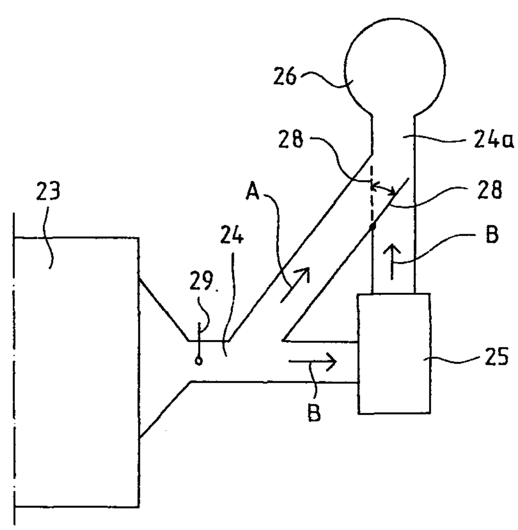
(71) Applicant: SAASTAMOINEN OY, SF-70101 Kuopio (FI)

(72) Inventor: Miettinen, Seppo, SF-58700 Sulkava (FI)

(74) Representative: Vossius Vossius Tauchner Heunemann
Rauh, Siebertstrasse 4 P.O. Box 86 07 67,
D-8000 München 86 (DE)

(54) **Control procedure for a boiler plant operating on solid fuel, and corresponding control apparatus.**

(57) The invention concerns a procedure for controlling the combustion process in a boiler plant operating on solid fuel, and a corresponding control apparatus. In the procedure, the excess air quantity is optimized on the basis of temperature measurement results, corresponding to various settings of the secondary air hatch, obtained from one temperature sensor (29) in the flue gas passage (24). By the procedure is found the setting of the secondary air hatch consistent with maximum flue gas temperature. The control apparatus comprises one single temperature sensor (29), placed in the flue gas passage (24) and a calculating unit, preferably a microcomputer. The apparatus also comprises a throttling damper (28) disposed in the flue gas passage (24), a primary air hatch, and a secondary air hatch to which the microcomputer with the aid of its optimation programme imparts the setting consistent with maximum flue gas temperature and optimum air excess.



EP 0 191 353 A1

VOSSIUS + PARTNER
PATENTANWÄLTE
8000 MÜNCHEN 86
SIEBERTSTRASSE 4
TELEFON 474075

0191353

Saastamoinen OY
u.Z.: U 327 EP

January 28, 1986

Control procedure for a boiler plant operating on solid fuel, and corresponding control apparatus

The present invention concerns a procedure for controlling the combustion process in a boiler plant operating on solid fuel, in said procedure the solid fuel being converted into combustible gases and the amount of secondary air supplied to the combustible gases for their combustion being regulated by controlling a secondary air control member.

At present, control of the combustion process in heating boilers has been by continuously measuring the oxygen and carbon dioxide content of the flue gas and performing the control on the basis of this direct measurement, by controlling the secondary air. Such control has also been common in which the primary and secondary air quantities are set to have constant values for each given rate of power output. In that instance, the settings of the primary and secondary air dampers have been found by estimating, in various ways, the goodness of combustion.

It is essential with a view to combustion that the excess air quantity is at its optimum. If too much secondary air is supplied, the fuel in the combustion volume does not need all the oxygen available in order to burn completely. This excess oxygen, and the corresponding proportion of the air, is however heated to the same temperature as the combustion gases, thus binding thermal energy and therefore cooling the flue gas. An inadequate secondary air quantity is not enough to burn all the gases fit to be burned, whereby carbon monoxide, in particular, gains access to the boiler's convection parts without being oxidized. This chemically bound energy escpaes from the combustion process, and the flue gas will not be heated up to the theoretical maximum. The maximum value of the flue gas temperature yields the best result of combustion.

As mentioned already, in designs consistent with the state of art have been known various combustion process controls based on measurements. Through the Finnish patent application No. 822332 is known a control procedure and apparatus for powdery fuel, or for dust firing. In the firebox has been disposed an optical flame monitoring means, which is susceptible to soot deposition. The procedure taught by said application interferes with the combustion process almost contiunuously (at 0.5 to 2 second intervals) and, on this account as well, it is therefore not appropriate, particularly not for solid fuels nor for so-called grate burning.

Through the German application print No. 2 756 284 is known a system which is intended for burning gaseous fuel. The fuel/combustion air ratio is determined in a separate control burner. In said system, a temperature sensor has to be mounted in, or close to, the flame.

Through the German application print No. 3 224 500 is known a measuring instrument which, admittedly, measures the flue gas temperature but which fails to apply its findings in any kind of control. The apparatus gives notice when the flame is too dark or when the flue gas is too hot, i.e., when the boiler is being run with excessive power output in relation to the momentary condition of the boiler.

In the German application print No. 3 330 990 is disclosed a procedure in which several separate boilers are so controlled that the generation of heat equals its consumption. Through this reference is known the dimensioning of these boilers and the control, in accordance with load variation, of igniting and extinguishing the burners in these boilers.

Through the U.S. Patent No. 4,375,950 is known a system which is intended to be used in controlling the burning of liquid and gaseous fuels. The system requires temperature sensors both in the firebox and in the flue duct. The apparatus is not applicable when burning solid fuels because the controller responds to disturbances of combustion independent of whether the disturbance is a prolonged change, e.g. of the fuel's moisture content, or for instance a temporary disturbance in the fuel supply. The correction applied on observing a disturbance of short duration in the combustion causes disturbances even after the time at which the original disturbance would have been amended without any aid. In the reference, the reaction of the system to load changes (to changes occurring in the fuel supply) is sluggish: the air quantity does not change until there has been a change in fuel supply. As a consequence, a controller like this system is constantly offset from the correct control value by a certain delay.

The object of the invention is to achieve an improvement of presently known control procedures for a boiler plant operating on solid fuel. The more detailed aim of the invention is to provide a control procedure which enables optimum combustion and better efficiency to be achieved. The other aims of the procedure of the invention, and the advantages gainable with its aid, will become apparent in the disclosure of the invention.

The aims of the invention are achieved with a control procedure for a boiler operating on solid fuel which is mainly characterized in that the combustion air quantity is optimized in that with a temperature sensor in the flue gas passage is measured the flue gas temperature at different settings of the secondary air control member, and a mathematical function is constructed which approximates the set of secondary air control member setting vs. temperature plots, the maximum flue gas temperature being solved therefrom, corresponding to this functon's maximum, and the setting of the secondary air control member is changed to be consistent with said setting of the secondary air control member, obtained as a result of optimizing.

The other important characteristic features of the control procedure of the invention are stated in claims 2 to 7.

It is also an object of the invention to provide a control apparatus for controlling the combustion process in a boiler plant operating on solid fuel. The control apparatus of the invention is mainly characterized in that the control apparatus comprises a calculator unit incorporating an optimation programme, and a secondary air control member controllable with the aid of set-point values derived from said calculator unit, and that the control apparatus comprises one single temperature sensor, installed in the flue gas passage, supplying to the calculator unit the results of temperature measurement, corresponding to different settings of the secondary air control member, required in optimizing the combustion air quantity.

The other characteristic features of the control apparatus of the invention are stated in claims 9 and 10.

In the present application is disclosed a new control procedure and apparatus for boiler plants operating on solid fuel. The heating center operating according to the forebox principle comprises a fuel supply assembly, a forebox, and a boiler with chimney. The burning means in the forebox converts the solid fuel into gaseous state. Said forebox burning means does not participate in the combustion process proper. The fuel runs from an intermediate silo onto an inclined grate, the embers glowing in this grate's lower part and on the planar grate drying the fuel and liberating the volatile gases therefrom. The carbon in the fuel becomes oxidized with the oxygen of the air supplied through the primary hatch, producing carbon monoxide. This gas mixture is not yet burned in the forebox; it is instead conducted by the fire tube into the boiler.

To the hot gas mixture coming from the forebox is added air from the secondary air connector of the firebox, whereby the gases are partly ignited in the fire tube and move, burning, into the boiler.

The basic idea of the invention, that is of the new control procedure and apparatus, is to accomplish control of combustion using only one thermocouple in the flue passage, measuring the flue gas temperature. Optimation of the combustion process takes place at the output power of the boiler at a given moment. For each output value a maximum can be found in the flue gas temperature when the secondary air quantity is varied. Said optimizing of combustion, and therewith maximizing of the combustion temperature, is accomplished with an apparatus in which the flue gas temperature is measured with a number of given secondary hatch settings, e.g. with three settings. This yields the pairs of measured values STA,SST; ATA,AST; YTA,YST, where SST is the flue gas temperature in the stable process prior to optimizing, AST is the flue gas temperature when burning with inadequate air quantity, ATA is the setting of the secondary damper when burning with inadequate air quantity, YST is the flue gas temperature when burning with ample air quantity, and YTA is the setting of the secondary damper when burning with ample air. These pairs of measured values represent a certain function, which represents the interrelationship of secondary damper setting and temperature. When the number of measuring points is three, the curve passing through the plots can be approximated with a parabola. The constants of this parabola are found by setting up simultaneous equations with the plots and solving these, for instance applying Cramer's method. Now once the equation including its coefficients has been found, it is further possible to find mathematically the maximum of the function, in this case of the parabola, whereby one finds the setting of the secondary damper corresponding to the maximum, and this setting will then give optimum combustion.

The excess air optimation is carried out at the power output of the heating centre at that particular moment, and therefore the secondary damper setting found in the way just described is only valid with this particular output rate.

The invention also comprises a throttling damper placed in the flue passage, and correction for the interdependence of the secondary air hatch settings. This correction is applied by establishing the set of plots $(sa,ta)_i$, where sa = the throttling damper setting and ta = the setting of the secondary hatch calculated by Equation (1), i = 1 to n, where n is the number of plots $(sa,ta)_i$. To the set of plots is further added the plot $(sa,ta)_{n+1}$, which contains the throttling damper setting during optimation and the optimum secondary air hatch setting. With these plots a so-called PNS fit is constructed, and the corrected Equation (1) is formed with the equation therefrom obtained.

The changed position of the secondary damper has no significant effect on the subatmospheric pressure in the firebox, and therefore there is no need to change the setting of the primary damper.

Setting of the secondary air damper =
= f (setting of the throttling damper) (1)

With the control procedure of the invention is obtained a control of a solid fuel boiler plant in which the air quantity is controlled without delay, simultaneously with the load, and always directly to the correct air/fuel ratio. This circumstance is, in fact, one of the significant factors when comparisons are made with control designs of prior art, in which it is typical that the air quantity does not change until there has been a change in fuel supply.

The procedure of the invention also comprises a step in which the combustion air quantity is checked at given intervals and, if required, correction is made so that through optimizing as taught by the invention is achieved a setting of the secondary air hatch consistent with maximum temperature of the flue gas. The interval between optimations may be one hour. This is advantageous because the influence of sporadic disturbances is then minimized.

The invention also concerns an apparatus consistent with the procedure, in this apparatus being essential that only one temperature sensor is employed, this thermocouple being located in the flue gas passage, and the apparatus comprising a calculating unit, suitably a microcomputer, which carries out the optimation consistent with the procedure just described, utilizing the measurement information obtained from said sensor, whereby as a result of the measurements and of the calculations made by the calculating unit, that is of the optimizing, is achieved a secondary air damper setting consistent with the excess air optimum. This excess air optimum quantity corresponds to the maximum of the temperature.

The invention shall be described in detail, referring to an advantageous embodiment of the invention, presented in the figures of the attached drawing, yet to which the invention is not meant to be exclucively confined.

Fig. 1 presents a boiler plant operating on solid fuel, in which the control procedure of the invention is applied, in elevational view.

Fig. 2 presents the boiler plant of Fig. 1, viewed from above.

Fig. 3 presents the boiler plant of Fig. 1, viewed from the front.

Fig. 4 shows on a larger scale, a detail of Fig. 2.

Fig. 5 shows graphically the relationship between secondary air quantity and flue gas temperature.

Fig. 6 illustrates graphically the optimation measurement taught by the invention.

The heating centre operating on solid fuel, depicted in Fig. 1, has been indicated in general with the reference numeral 10. The solid fuel storage bin is indicated with reference numeral 11. The storage bin 11 has an openable cover structure 12, and the lower part 13 of the storage bin 11 is tapering. Reference numeral 14 indicates a plunger feeder, arranged to move solid fuel from the storage bin 11 by a transport tube 15 to the intermediate silo 16. A limit switch 17 has been fitted to control the supply of solid fuel to the intermediate silo 16 so that the intermediate silo 16 is substantially filled to capacity all the time.

The heating centre 10 comprises a forebox 18, this being a burning means which converts the solid fuel, for instance chipped wood, sawdust, lump peat, to gaseous state without participating in the ultimate combustion process. The fuel runs from the intermediate silo 16 e.g. down on an inclined grate, the embers glowing in its lower part and on the planar grate drying the fuel and liberating therefrom the volatile gases. The carbon in the fuel is oxidixed with the oxygen in the air supplied through the primary air hatch

19, producing carbon monoxide. This gas mixture is not burned in the forebox 18; it is conducted by the fire tube 21 into the boiler 23.

Filling of the forebox 18 is automatically accomplished with the aid of a feeder, e.g. a plunger feeder, 14 connected to the intermediate silo 16. This system keeps the intermediate silo 16 filled to capacity at all times, independent of the fuel consumption. To the hot gas mixture coming from the forebox 18 is added air through the secondary air hatch 22 on the fire tube 21, whereby the gases are partly ignited in the fire tube 21 and go, burning, to the boiler 23. An action means 20 has been provided to control the primary air hatch 19, i.e., to change the setting of the primary air hatch 19. The reference numeral 26 indicates the chimney and numeral 27, the base on which the forebox 18, boiler 23 and chimney 26 have been erected.

The thermocouple 29 measuring the flue gas temperature has been placed in the flue passage 24.

As shown in Fig. 4, a flue gas exhauster 25 has been mounted in the flue passage 24. The part after the exhauster 25 of the flue passage 24 carries the reference numeral 24a. In Fig. 4, the flow of flue gases under natural draught is indicated by the arrow A and that with forced draught, by the arrow B.

The procedure of the invention now comprises a step in which with a thermoelement 29, suitably a thermocouple, in the flue gas passage is measured the flue gas temperature at a plurality of points. It is shown in Fig. 5 that with optimum excess air quantity and with a given setting of the secondary air hatch 22 optimum combustion is achieved, whereat the flue gas temperature has its maximum. If through the secondary air hatch 22 too little air is admitted into the fire tube 21, not enough oxygen is obtained for the combustion, while in the event that there is too much air the excess air binds thermal energy and the energy bound in this manner is wasted. When now the flue gas temperature is measured, as taught by the invention, at three points, three pairs of values are obtained in each of which to a certain setting of the secondary air hatch corresponds a certain flue gas temperature. One obtains the plots (STA,SST); (ATA,AST); (YTA,YST), where SST = flue gas temperature in a stable process before optimizing, STA = setting of the secondary air hatch 22 before optimizing, AST =flue gas temperature when burning with inadequate air quantity, ATA = setting of the secondary air hatch 22 when burning with inadequate air quantity, YST = flue gas temperature when burning with ample air quantity, YTA = setting of the secondary air hatch 22 when burning with ample air quantity. The curve passing through the plots that have been found is approximated with a parabola, of which the constants are found by setting up simultaneous equations with the plots and by solving them e.g. with the aid of Cramer's method or by another mathematical method. The setting of the secondary air hatch 22 corresponding to the maximum of the curve gives optimum combustion. The idea is that a mathematical function representing the relationship between the flue gas temperature and the setting of the secondary air hatch 22 is constructed in which the variables are temperature and setting of the secondary air hatch 22. To the maximum of said curve, i.e., to the point where the temperature has its maximum, corresponds a given setting of the secondary air hatch 22. The secondary air hatch 22 is now set in this particular position with the aid of the control equipment. There may also be more than three points of measurement, but the measurement at three points which has been described is sufficient.

Optimizing is achieved with a calculating apparatus, suitably a microcomputer, in which the optimation process has been programmed. The sensor 29 in the flue passage 24 measuring the flue gas temperature is suitably a thermocouple, because the temperature here is already reasonably low and a thermocouple is then better resistant. The fact that only one sensor 29 is needed has also a favourable effect on the price of the whole control equipment.

In the procedure of the invention is also performed correction for the relationship between the settings of the throttling damper 28 inserted in the flue passage 24 and of the secondary air hatch 22. This correction is made by setting up a set of plots (sa,ta), where sa = setting of the throttling damper 28, ta = settings of the secondary air hatch 22 calculated from Equation (1), i = 1...n, where n is the number of plots $(sa,ta)_i$. To the set of plots is further added a plot $(sa,ta)_{n+1}$ which contains the flue damper setting and the optimum secondary air hatch setting during optimizing. With these plots a so-called PNS fit is sought and the equation derived therefrom is used to produce the corrected Equation (1). The changed setting of the secondary damper has little effect on the subatmospheric pressure in the boiler firebox 23, and no correction of the primary air hatch 19 is therefore necessary.

Setting of the secondary air damper =

= f (setting of the throttling damper) (1)

Fig. 6 illustrates an optimizing measurement. Everything takes place on one time axis. Topmost is shown the course of the flue gas temperature. The lower graphic presentation, again, represents the settings of the secondary air hatch at the different steps. The abbreviations (SST,AST, YST and STA,ATA,YTA) correspond to the points of measurement, already discussed, associated with the optimizing run.

Claims

1. Procedure for controlling the combustion process in a boiler plant operating on solid fuel, wherein the solid fuel is converted into combustible gases and the quantity of the secondary air supplied to said combustible gases for their burning is regulated by controlling a secondary air control member (22), characterized in that the combustion air quantity is optimized in that with a temperature sensor (29) in the flue passage (24) is measured the flue gas temperature at various settings of the secondary air control member (22) and a mathematical function approximating the secondary air control member (22) setting/temperature plots thus obtained is constructed, its maximum consistent with maximum flue gas temperature being solved, and the setting of the secondary air control member (22) is changed to conform to the respective setting of the secondary air control member (22) found as result of optimizing.

2. Procedure according to claim 1, characterized in that for performing the optimation, three flue gas temperature measurements are made at three different settings of the secondary air control member (22), and that the curve passing through said three points of measurement (STA,SST;ATA,AST;YTA;UST) is approximated with a parabola, the maximum of said parabola being found, and the secondary air control member (22) being set in the position yielding said optimum combustion and maximum temperature.

3. Procedure according to claim 2, characterized in that the constants of the parabola passing through the points of measurement are found when a group of simultaneous equations is constructed from these plots and this is mathematically solved, e.g. applying Cramer's method.

4. Procedure according to any one of claims 1-3, characterized in that the relationship between the settings of the flue gas flow control member (28) and the secondary air control member (22) is corrected with a value obtained by optimation and stating the setting of the flue gas flow control member (28) and the setting of the secondary air control member (22).

5. Procedure according to any one of claims 1-4, characterized in that the relationship between the settings of the flue gas flow control member (28) and the secondary air control member (22) is corrected by setting up a set of plots $(sa,ta)_i$, i = 1...n, where sa = setting of the flue gas flow control member (28) and ta = setting of the secondary air control member (22), and in said set of plots is further incorporated a plot $(sa,ta)_{n+1}$ which contains the setting of the flue gas flow control member (28) during optimizing and the secondary air control member (22) setting found by optimizing, and for the plots thus obtained a curve fit is carried out and with the aid of the fitted curve is formed the corrected equation

Setting of the secondary air damper (22) =
= f (setting of the flue gas flow control member (28)) (1)

6. Procedure according to any one of claims 1-5, characterized in that optimizing takes place at given intervals.

7. Procedure according to claim 6, characterized in that the interval between optimations is about one hour.

8. Control apparatus for controlling the combustion process in a solid fuel boiler plant, applying a procedure according to any one of claims 1-7, characterized in that the control apparatus comprises a calculator unit containing an optimation programme and a secondary air control member (22) controllable with the aid of the set-point values coming from said calculating unit, and that the control apparatus comprises one single temperature sensor (29) placed in the flue gas passage (24) and which produces for the calculating unit the temperature measurement results corresponding to various settings of the secondary air control member (22) which are needed for optimizing the combustion air quantity.

9. Control apparatus according to claim 8, characterized in that the calculating unit is a microcomputer.

10. Control apparatus according to claim 8 or 9, characterized in that the temperature sensor (29) is a thermocouple.

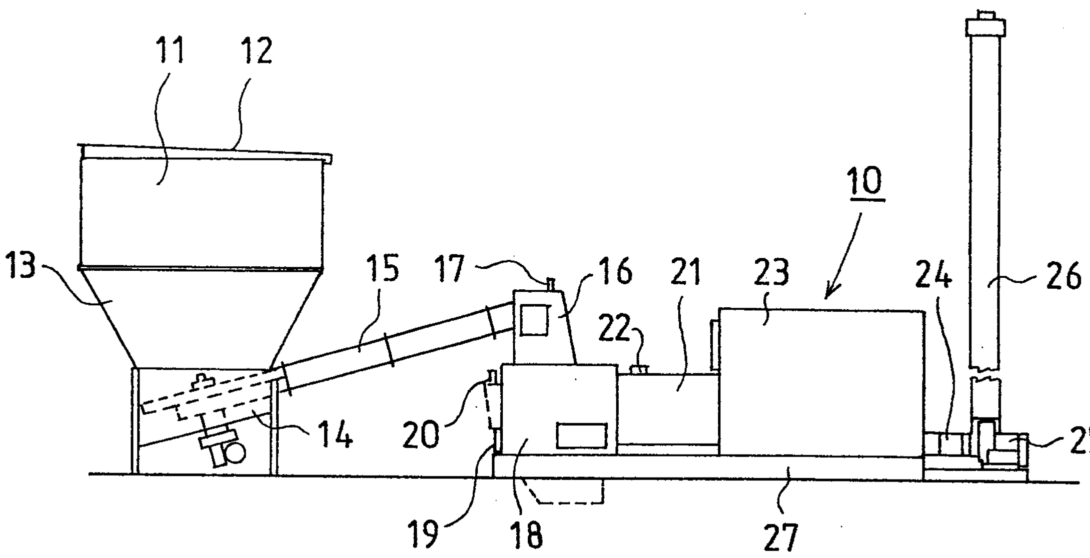

11
12
13
15
17
16
21
23
10
24
26
22
20
14
25
19
18
27

FIG. 1

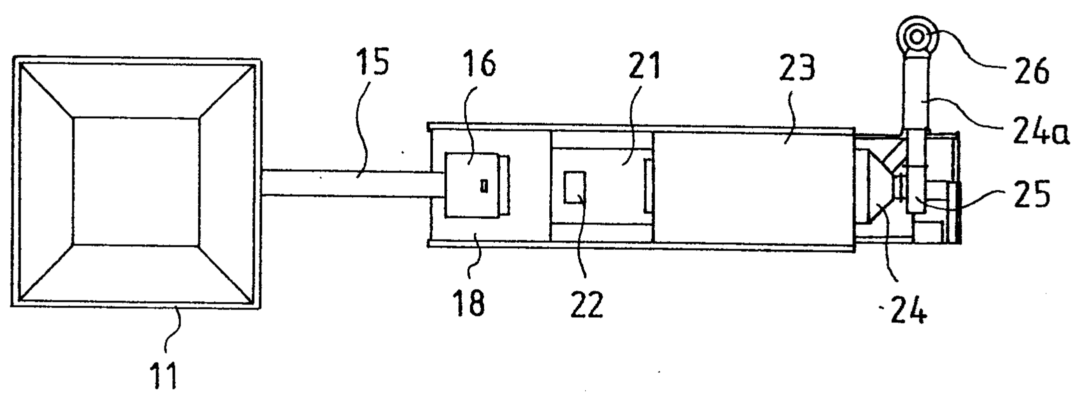

15
16
21
23
26
24a
25
18
22
24
11

FIG. 2

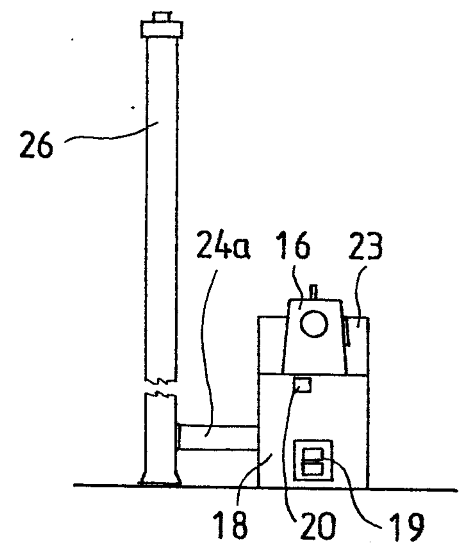


FIG. 3

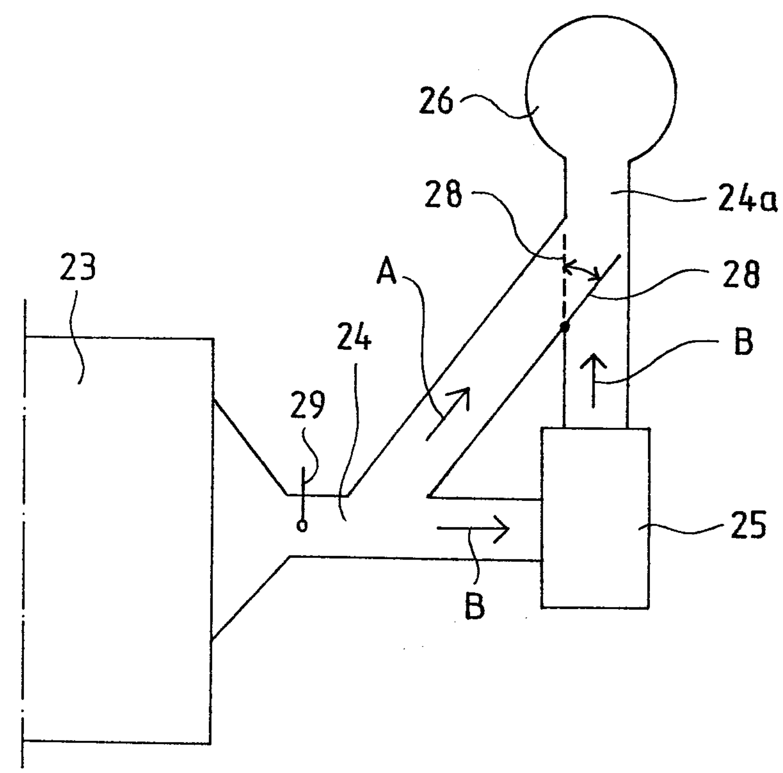


FIG. 4

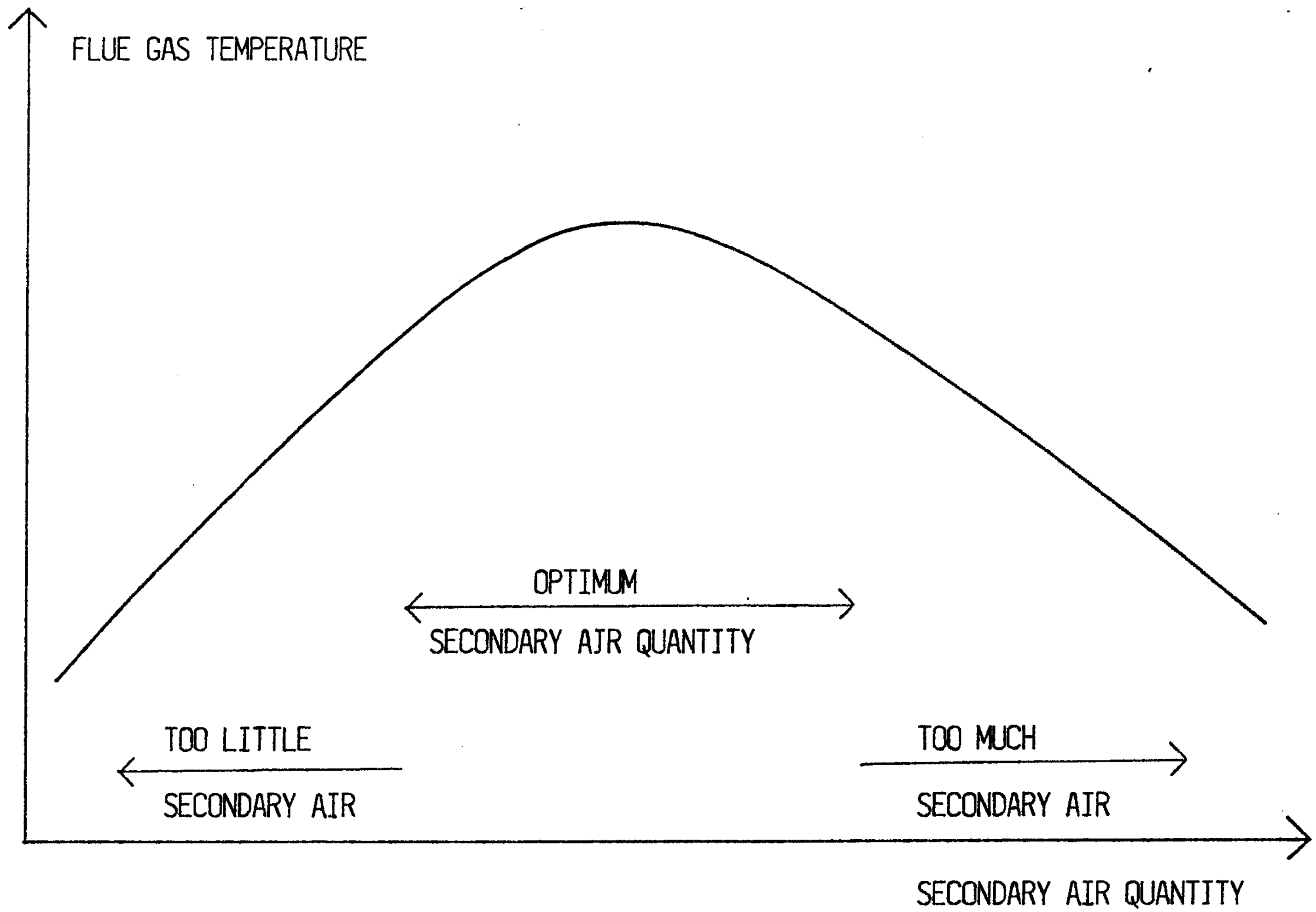

FLUE GAS TEMPERATURE
OPTIMUM
SECONDARY AJR QUANTITY
TOO LITTLE
SECONDARY AIR
TOO MUCH
SECONDARY AIR
SECONDARY AIR QUANTITY

FIG. 5

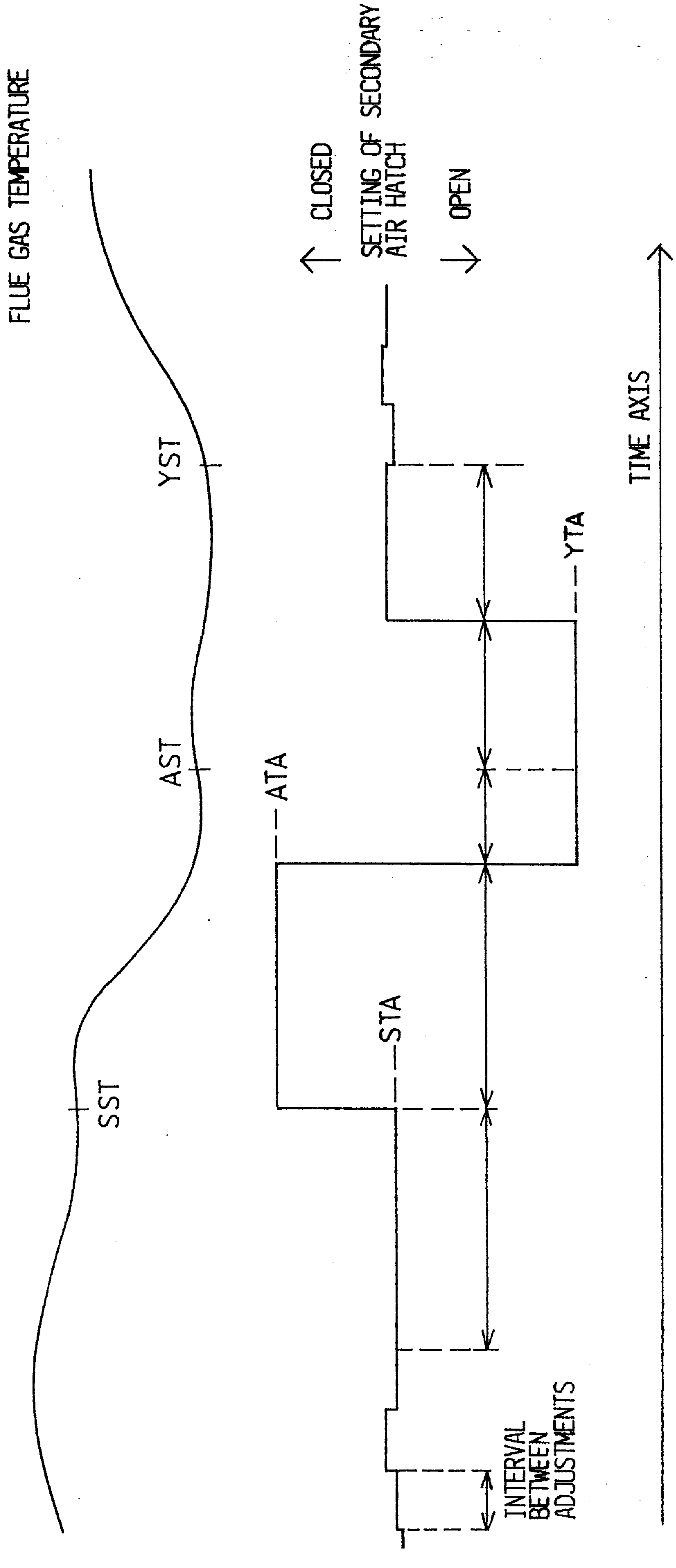

FLUE GAS TEMPERATURE
SST
AST
YST
CLOSED
SETTING OF SECONDARY AIR HATCH
OPEN
STA
ATA
YTA
INTERVAL BETWEEN ADJUSTMENTS
TIME AXIS

FIG.6

European Patent Office

EUROPEAN SEARCH REPORT

0191353
Application number

EP 86 10 1087

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.4)
A	DE-A-3 315 199 (SCHAVEG AG) * Claims 1,4 *	1	F 23 N 1/02
A	DE-A-3 221 660 (P.G. GILLI) * Abstract; claims 1-21 *	1,4,8, 9	
A	EP-A-0 124 330 (AUTOFLAME ENGINEERING LTD.) * Abstract; figures 1,4a,4b *	1	
A	EP-A-0 050 840 (K. DUNGS GmbH & CO.)		
A	US-A-3 960 320 (B.R. SLATER)		TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	GB-A-2 117 876 (STONE PLATT FLUIDFIRE LTD.)		F 23 N F 23 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14-05-1986	THIBO F.

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

EPO Form 1503 03.82