

(19)



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(11)

EP 1 322 893 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
13.04.2005 Bulletin 2005/15

(51) Int Cl.7: **F23N 1/00**, F23N 5/00,
F23B 1/32

(21) Application number: **01972889.8**

(86) International application number:
PCT/SE2001/002159

(22) Date of filing: **05.10.2001**

(87) International publication number:
WO 2002/029326 (11.04.2002 Gazette 2002/15)

(54) **METHOD FOR AUTOMATIC CONTROL OF A BURNER FOR SOLID FUEL**

VERFAHREN ZUR AUTOMATISCHEN STEUERUNG EINES FESTBRENNSTOFFBRENNERS

PROCEDE DE COMMANDE AUTOMATIQUE D'UN BRULEUR A COMBUSTIBLE SOLIDE

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**

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(30) Priority: **06.10.2000 SE 0003600**

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(43) Date of publication of application:
02.07.2003 Bulletin 2003/27

(56) References cited:
WO-A1-99/28678 DE-U1- 20 007 801

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Description

[0001] The invention relates to a method for automatized combustion of solid fuel in a combustion apparatus which comprises a burner, which is connected to a boiler and has a feeding-in opening for fuel and an outlet opening which opens in a combustion chamber inside the boiler, which comprises a convection unit and a flue gas pipe for waste flue gases containing CO₂ and not combusted O₂, the combustion apparatus comprising a device for feeding combustion air into the burner, and a fuel charge feeder for fuel provided to be driven by a motor, here called fuel charge feeding motor, the operation of the fuel charge feeding motor being regulated by commands from a control unit in dependency on measured values transmitted to the control unit and in dependency of the heat power the burner shall generate, and a measuring device arranged for measuring the content of CO₂ and/or O₂ in the flue gases.

BACKGROUND OF THE INVENTION

[0002] Solid fuels have a number of significant advantages before fuel oil; they are generally cheaper, they are available in large amounts, and they take part in a natural circulation and do not cause pollution load on the environment in spite of their emission of carbon dioxide, since they are based on wood or other renewable bio-products. Nevertheless, solid fuels are used to a comparatively small degree in the modern society. The main reason for this condition probably is that it is easy to automatize combustion of fuel oil but comparatively difficult to automatize combustion of solid fuel, and it is particularly difficult to automatize solid fuel combustion in order to provide an efficient combustion at all power levels without emission of products with the fuel gases which are harmful to the environment.

[0003] By e.g. WO99/28678 is shown a combustion apparatus for solid fuel that in an efficient way solves much of the complex of problems concerning automatic control. However, like other known devices in the field, difficulties of control may, during certain circumstances, lead to undesired maintenance and/or undesired complexity regarding control programs and/or included equipment. The background is that the demands put forward nowadays on a combustion apparatus for solid fuel, mean that qualities are expected that when it comes to emissions respond to the best combustion apparatus for fuel oil. A specific problem connected to solid fuel, that does not exist concerning combustion apparatus for fuel oil, is the difference in quality between different deliveries, and also in the same delivery. Often, solid fuel varies in weight by unit of volume, density and size between different shipments, but sometimes also in the same shipment. Thus, the optimization of the combustion efficiency of a combustion apparatus for solid fuel is made difficult by a constantly varying weight by unit of volume of the fuel. From efficiency point of view it is

desired that practically all of the oxygen supplied to the combustion chamber is used after a completely finished combustion, i.e. in the flue gases that are emitted through a flue gas pipe. However, the fact is that if an insufficient amount of oxygen is supplied to the combustion chamber, not combusted pyrolytic gases will be produced meaning a risk of explosion.

[0004] In connection with combustion apparatus for solid fuel, it has turned out that the supervision staff, to be on the safe side, often lowers the setting of the fuel, making it never possible for variations in fuel quality to cause saturation. Instead, a higher surplus of air and by that a lower rate of efficiency is accepted. Accordingly, the reason for this being the case is the constantly varying weight by unit of volume of the solid fuel, combined with difficulties to be able to optimize the rate of efficiency safely. Among other things, the difficulty in optimizing is due to the long time delay between the combustion and the possibility to be able to establish change of the rates in the flue gases, i.e. long time passes from the point where new fuel starts to combust until the point where the flue gases from this new fuel may be measured and analysed.

[0005] Trials made so far to automatically control the combustion, have always been based on changing the air supply. Through changing the air supply also other variables decisive for how the combustion is done, and by that which amount of residual content of oxygen obtained in the combustion gases, are changed. Many different trials aiming this way are made but so far, from different reasons, no satisfactory solution to the complex of problems exists.

[0006] It is true that in DE-U-20007801 there is a procedure already described, according to the preamble of claim 1, wherein the measuring device transmits a measuring signal to the control unit regarding the contents of the flue gas, the contents of the flue gas being regulated by means of the control unit regulating the fuel charge feeding motor regarding the measured values of the flue gases. The combustion air supply is kept essentially constant during the period of time when the control of the contents of the flue gas is being done. Through this, some of the above said problems are eliminated, but due to the procedure being meant for continuous feeding, there are still essential control difficulties. This is related to the long time delay between the combustion and the possibility to be able to establish change of the rates in the flue gases. Also, it is a serious problem that the fuel charge feeding screw has to work at different rotation rates, which, among other things, means that the motor must be overcompensated to guarantee operation even at low rotation rates due to the regulation of rotation rate. Further more, it adds, in itself, a difficulty in regulation technique to be able to handle a continuously variable rotation rate, particularly when this, in many cases, has to be adjusted to varied set values.

BRIEF DISCLOSURE OF THE INVENTION

[0007] It is the purpose of the invention to solve the said problems, which is achieved by a procedure of the kind mentioned in the preamble, characterized by the fuel charge feeding motor works intermittently and feed fuel charges to the burner, and by, in case of the measuring signal from the measuring device having reference to the contents of the flue gases is beyond a set value, the control unit influences the operation time of the fuel charge feeding motor depending of the value of the measuring signal, either increasing or reducing the operation time to adjust the contents of the flue gas to a desired set value, maintaining an optimal content of the gas measured by the measuring device in the flue gas pipe.

[0008] Thanks to this new thinking many unexpected advantages are gained and it is possible to, in a safe way, make sure that the combustion apparatus operates at top efficiency and at the same time eliminate the risk of explosion. Further more, surprisingly, it has been shown that the length of life of the material of the drum's interior increases substantially, up to doubled length of life. Likely, this is related to the optimized residual oxygen content during the combustion.

[0009] According to further aspects of the invention

- the air supply is provided for by means of a fan driven by a motor keeping its rotation rate at a constant level during said regulation of the flue gas contents;
- a larger change of the operation time of the fuel charge feeding motor is made if the residual oxygen content is above the set value;
- after performing a change in the operation time of the fuel charge feeding motor, a certain time interval is allowed to pass, before a possible additional regulation is performed, in order to await a necessary time delay with the purpose of seeing the power of the latest performed change, the time interval being preferably between 30 s and 5 min, more preferred over 1 min, the regulation change of the length of pulses of the fuel charge feeding motor being at least twice greater at an adjustment downwards than at an adjustment upwards;
- at least the greater part of the motors included in the combustion apparatus, preferably a stirring motor, an fan motor and a fuel charge feeding motor are rotated according to a number of different programs, corresponding to the same number of different power levels, which are divided between a lowest power level for keep-alive combustion and a top power level, the temperature of the hot water in the hot water conduit preferably being transmitted to a control unit for automatic choosing of power level; and
- that the fuel charge feeder by means of the fuel charge feeding motor delivers the fuel in the form of charges to the feeding-in device operating in a

more continuous mode than the fuel charge feeder and distributing the charged fuel so that it is fed into the burner as an evened out flow.

[0010] Further characteristics and aspects of the inventions will be apparent from the following description of a preferred embodiment.

BRIEF DESCRIPTION OF DRAWINGS

[0011] In the following description of a preferred embodiment of the invention, reference will be made to the accompanying drawings, in which

Fig. 1 illustrates, partly schematically, the automated combustion apparatus according to the invention;

Fig. 2 shows a preferred movement pattern of a fuel charge feeding device suitable to be used with the invention,

Fig. 3 shows an power/power mode graph of a control program suitable to be used with the invention, Fig. 4 shows a preferred embodiment of power optimization according to the invention, and,

Fig. 5 shows the same as Fig. 4 but in different circumstances.

DETAILED DESCRIPTION OF THE INVENTION

[0012] In Fig.1 is shown as an example, a combustion apparatus, which may well be adapted to operate according to the invention. The main units of the combustion apparatus consist of a burner assembly 100, a fuel charge feeder assembly 200, and a control unit 300. The burner assembly 100 is connected to a schematically shown boiler 400, which may be of a conventional kind. In the boiler 400 there is a combustion chamber 401 connected to a convection part 402. To the convection part 402 there is connected conduits 403 for hot water, and a flue gas pipe 407 for removal of the combustion gases/flue gases. In the flue gas pipe 407 there is provided a measuring device 408 meant to transmit the content of residual oxygen in the combustion gases to the control unit 300. Suitably, this measuring device 408 is constituted by a lambda-probe. In the hot water conduit 403 there is a temperature sensor that transmits the temperature of the hot water to the control unit 300.

[0013] In the burner assembly 100 is included a solid fuel burner 1, which according to the shown, preferred embodiment is circular-cylindrical and is rotatable about a slightly inclined axis of rotation. It has an outer flange 24 for mounting the whole burner assembly 100 on a boiler door of the schematically shown boiler 400, such that an opening 3 for the combustion gases in the front end of the burner will mouth in the combustion chamber 401 of the boiler. The interior of the burner forms a main or primary combustion chamber 13 and an after- or secondary combustion chamber 14.

[0014] Other components of the burner assembly 100 consist of a fan 27 for combustion air, a fan motor 22, in this text also called second motor, for rotation of the fan 27 (as an alternative, two or more fans with accompanying motors can be provided, including one fan with its motor for blowing primary combustion air into the main or primary combustion chamber 13 and another fan with its motor for blowing secondary combustion air into the after- or secondary combustion chamber 14), a coreless feeding-in screw 40 in a fuel feeding-in tube 18 for a particle shaped solid fuel, a feeding-in motor 41, in this text also called fourth motor, for rotation of the feeding-in screw 40, a stirring motor 34, in this text also called first motor, for rotation of the reactor drum 1 about the inclined axis 2 of rotation, and the lower part of a down-pipe 42 for the fuel. The sloping angle of the reactor drum 1 to the horizontal plane, with the reactor drum's front opening 3 for combustion gas directed obliquely upwards, amounts to ca 8-15° depending on size, the sloping angle being reduced as the size increases.

[0015] The rear end wall of the reactor drum 1 is double-walled, as is the main part of its cylindrical part. The space between the inner 65, 66 and the outer walls is denoted 54. The inner walls 65, 66 are provided with holes 55 in the cylindrical part as well as in the rear end part for the introduction of combustion air into the main burner chamber 13. The holes in the inner cylindrical wall 66 are more dense in the rear part of the primary combustion chamber 13 and somewhat more sparsely distributed in the front part. Furthermore, the intermediate space 54 is divided into channels through longitudinal, radially directed, lamella-shaped partition walls in the cylindrical part of the reactor drum, and in the rear end of the drum there are partition walls which form between themselves circular sector-shaped channels for combustion air. The partition walls in the rear part are connected to those in the cylindrical part so that each circular sector-shaped channel in the end wall communicates with a longitudinal channel in the cylindrical part but only with one and not with any more such longitudinal channel. The air streams through these channels can be regulated by means of valve members which are not shown, causing the combustion air in the first place or substantially to be guided into the lower, rear parts of the combustion chamber, which are located beneath an interior, smaller drum 60 in the rear part of the reactor drum 1, as will be described more in detail in the following. The combustion air thus in the first place or substantially is introduced into those parts of the main combustion chamber 13 where the fuel is collected during the combustion. As an alternative or as a complement two or more fans can be provided, which transport air to the primary combustion- and to the secondary combustion chamber, respectively, as has been mentioned above. This can be particularly advantageous for burners for high powers, i.e. in the order of size of 1 MW or more.

[0016] The rear, inner wall 65 of the drum 1 and par-

ticularly the rear part of the cylindrical inner wall 65 of the drum 1 constitutes the fire grate of the burner 1. At the same time, the drum with its inner walls forms a rotatable device for stirring the fuel in the burner. In order further to secure stirring of the fuel, activators 56 are provided on the inside of the reactor drum 1, said activators extending all the way back to the end wall 65 and follow the rotation of the reactor drum 1.

[0017] The inner, smaller drum 60 is cylindrical and has a perforated jacket. According to the embodiment, the drum consists of a sheet metal drum with holes in the jacket, but a net drum is also conceivable. The holes in the jacket are designated 61. These are so small - the diameter or greatest extension amounts to 10 mm maximum, preferably 8 mm maximum - that the fuel particles can not pass through them to any considerable degree. In front, the drum 60 is completely open. This opening is designated 62. The drum 60 is co-axial with the reactor drum 1 and surrounds a central feed opening 63, which forms the mouth of the feeding-in tube 18 for the fuel, which is fed in by the feeding-in screw 40. The diameter of the drum 60 is somewhat larger than the opening 63. In the annular space 64 between the feeding-in opening 63 and the drum 60, the rear end wall 65 of the reactor drum 1 has no inlet openings for combustion air. The drum 60 is welded to the rear end wall of the reactor drum 1. The fuel feeding-in tube 18 is surrounded by a concentric, tubular driving shaft 19, which at the same time serves as an air injection pipe. In the cylindrical space 20 between the feeding-in tube 18 and the driving shaft 19 there are, in same mode as in the cylindrical space 54 between the cylindrical outer and inner walls of the drum, longitudinal, radially directed partition walls extending between the tube 18 and the shaft 19, so that longitudinal channels are defined between said walls in the same way as the channels between the walls in the cylindrical part of the drum 1. Each partition wall in the space 20 thus is connected with one and only one partition wall in the space 54. Thus there is formed a system of channels which are separated from each other - according to the embodiment eight such channels - which extend from the rear end of the tube 19 all the way to the front end of the main combustion chamber 13, where the channels are closed by an annular end wall 47.

[0018] The rear part of the drum 1, approximately corresponding to the half length of the drum, it is surrounded by a double walled casing 25, which is obliquely cut off at an angle which corresponds to the angle of inclination of the drum and is terminated by said flange 24 for mounting the burner assembly on a boiler door or boiler wall by means of screws. That part of the device which in Fig. 1 is to the left of the flange 24 thus extends into the combustion chamber 401 in the boiler 400, while the parts to the right of the flange 24 are located outside of the boiler.

[0019] The combustion air is drawn in by the fan 27 through an air intake 27A and is pushed via air conduits 51 and via the not shown valve system (a throttle) into

the air injection pipe/shaft 19, and from the interior 20 thereof, further on into the channels in the intermediate space 54 and finally through the holes 55 into the combustion chamber 13.

[0020] For the driving of the fan 27, the drum 1, and the feeding-in screw 40 by the fan motor 22, the stirring motor 34, and the feeding-in motor 41, respectively, there are provided transmissions (not shown), which, however, in a conventional mode may consist of axles, chains, belts, or other conventional elements. The feeding-in screw 40 is arranged to be rotated by the feeding in motor in a direction opposite to that of the drum 1.

[0021] The fuel that falls down in the down-pipe 42 is immediately proceeded further on by the feeding-in screw 40. If, because of any malfunction, the feeding-in screw 40 would not transport the fuel fast enough to keep pace with the fuel that it is falling down through the down-pipe 42, some amount of fuel will collect in the lower part of the down-pipe 42. This is not desirable, above all from a safety point of view. Therefore, in order to limit such possibly collected amount of fuel, a level guard 70 is located in the down-pipe 42 to transmit a signal to the control unit 300, if the amount of fuel in the lower part of the down-pipe would rise up to the level guard 70, so that further transportation of fuel to the down-pipe 42 is stopped. According to the embodiment, this volume amounts only to 3 litres. In the lower part of the down-pipe 42 there is also provided a temperature guard 71, which is provided to transmit a signal to the control unit 300, if the temperature would rise to a certain, set temperature, so that the burner is emergency stopped, which implies that the feeding-in of fuel and of combustion air to the burner is stopped as well as the rotation of the drum. As an additional safety measurement, a section 72 of the down-pipe consists of non-combustible plastic hose, which is melted off if the temperature in the down-pipe in said section nevertheless would exceed a certain temperature. Further, as still another safety measurement, the upper section 73 of the down-pipe is laterally displaced, so that any fuel will not fall down on the burner assembly, if the plastic section 70 would be melted off.

[0022] It is realized that the shown burner assembly 100 can be modified within wide scopes. For example, the rotating drum 1, whether it contains an inner, smaller drum 60 or not, can be positioned completely horizontally. In this case, however, the drum should be made tapered, i.e. conically tapered, from the rear wall and forwards, so that the bottom of the drum will get approximately the same level of inclination as has been shown in the described embodiments, whereby the fuel also in this case will be collected on the bottom of the rear part of the drum, where the injection of primary air is concentrated. One can further conceive that there does not exist any sharp corner in the transition between the rear end wall and the side wall which corresponds to the jacket of the drum but instead, e.g. a bevelled transition. A burner which is completely void of corners, e.g. a burner

with the substantial shape of an egg or pear cut off at both ends, in which the more pointed part is directed forwards towards the outlet opening, however, is a design which is most suitable from some points of view. Also in this case, suitably, the burner is double-walled with the intermediate space between the walls divided into channels, or otherwise provided with channels for combustion air from the air inlet pipe, which surrounds the central fuel feeding-in pipe, and further outwards and forwards.

[0023] The fuel charge feeding assembly 200 according to the shown, preferred embodiment is connected to a storage container 201 for particle shaped fuel 202, preferably pellets, via an external conveyer screw 203, which is rotatable in a conveyer tube 204 obliquely upwards by means of a fifth motor, here called external motor 205. In the upper end of the conveyer tube 203 the conveyed fuel falls down through a down shaft 207 to a transitory fuel storage 208.

[0024] A fuel charge feeding tube 210, which slopes upwards, has a rear inlet opening for fuel from the transitory storage 208. In the fuel charge feeding tube 210 there is a fuel charge feeding screw 212, which is rotatable with variable frequency, particularly intermittently rotatable, by means of a fuel charge feeding motor 211. The tube 210 in its upper end terminates in the upper feeding in end of the down-pipe 42, where a smoke-detector 213 is located and provided to transmit a signal to the control unit 300 in case of smoke in the down-pipe 42 in order to stop all motors in the combustion apparatus. A temperature guard 217 is located in the upper part of, or above, the down-pipe 42. If the temperature in the region of the temperature guard 217 would rise to a certain, set value, the temperature guard 217, which is not dependent on electric current, transmits a command directly to a non-current-depending valve, so that water is supplied to a sprinkler 214 at top of the down-pipe 42 for water-soaking of the overheated region.

[0025] The principles for the mode of operation of the shown combustion apparatus are based on the control unit being provided to be set at a number of fixed power levels; according to the embodiment at eight power levels. The invention's principle of employing a number of fixed power levels significantly facilitates the trimming of the apparatus. With "power level" shall be understood that the burner 1 at each power level shall generate a certain heating power, which can be utilized in the convection unit 402 of the boiler 400 for heating the water in the boiler 400. In an example of application, which does not limit the principles of the invention, the maximum power of the burner is 100 kW, which corresponds to power level E8, see Fig. 3. Power level E1 is a keep-alive level, at which the burner generates 2 kW. At the power levels B2, E3, E4 ... E7 the burner 1 shall generate 10, 25, 40, 55, 70, and 85 kW, respectively, through control by the control unit 300. The temperature of the water in a hot water conduit 403 is suitably measured by means of a resistive type thermometer 404, which

transmits an analogue signal with a magnitude in relation to the temperature. The measure signal is transmitted via an analogue-digital-converter 405, Fig. 5, to a main-CPU 308 (Computer Processing Unit, i.e. a micro-processor or a so called PROM) in the control unit 300. The basic principle is that the generated power of the burner 1 is changed to a higher power level, e.g. from power level E6, at which the burner generates 70 kW, to power level E7, at which the burner generates 85 kW, if the temperature in the hot water conduit 403 would drop a certain pre-set margin below a certain set value, e.g. 80°C. In a corresponding way there is a change to a lower power level, if the temperature in the hot water conduit 403 would rise above the upper margin of the set value. In this way the generated power of the burner may hover between certain fixed power levels, which, however, does not mean, as will be apparent from the following, that the mode of operation of the combustion apparatus gets a choppy character. To the contrary the change between the different power levels take place smoothly in spite of its seemingly jumpy character, which is calculated to give a high combustion efficiency and a very low emission of undesired products in the flue gases. How the burner assembly 100 and the fuel charge feeder assembly 200 work in co-operation with each other in dependency of the control unit 300 at the different power levels now shall be explained, assuming, to simplify, that the residual oxygen content is within an acceptable interval.

[0026] In Fig. 2 is shown schematically the intermittent movement patterns of the burner and the fuel charge feeding screw 212, respectively. Thereby, the fan motor 22 and other motors are rotating in connection with steady-state with speeds that are adapted to each other in such a way that the amount per time unit of combustion air blown in, corresponds to the amount per time unit of fuel charged to achieve optimal combustion. Combustion air is thereby drawn in through the intake 27A and is blown via the conduit 51 in through the openings 55 in the walls 65, 55 of the fire grate/burner 1. The burner 1 is rotated intermittently in 1 s pulses alternating with 3 s periods of rest. The fuel charge feeding screw 212 feeds fuel charges intermittently during 5 s pulses alternating with 40 s periods of rest, when the fuel charge feeding screw does not move. The fuel charge feeding screw 212 fetches the pellets from the transitory storage 208 which always is kept filled by means of the external screw 203 and its motor 205, which starts operating as soon as the fuel level in the transitory storage 208 has dropped below a certain level, which is registered by a level indicator 215 which is located there and which via the control unit 300 stops the external motor 205.

[0027] The charges of pellets, which fall down through the down-pipe 42 fall all the way down into the feeding-in tube 18 and are successively moved forwards by the continuously rotating feeding-in screw 40. At the same time as they are moved forwards in the tube 18 by the

screw 40, the pellets are also spread out, i.e. the charges that fall down through the down-pipe 42 to the screw 40 are distributed by the screw 40 so that the fuel that is delivered to the inner basket has the form of a comparatively smooth flow. The levelling out power is magnified by the fact that the screw 40 does not have any core. In the basket 60 the pellets are preheated before the fuel leaves the drum/basket 60 through its opening 62 so that it in the form of flow, which has been still more levelled out in the drum/basket 60, falls down on the inclined bottom/grate defined by the inner, perforated jacket 66 of the burner/drum 1.

[0028] Through the setting of the fuel charging and of the amount of combustion air according to the control program, the burner will generate 10 kW in power level E2 shortly after change of power level according to the example. In case of insufficient power a shift to power level E3 (see Fig. 3) automatically is performed to increase the output power after a period of time, which also is set in the control program.

[0029] At power level E3-E8 the burner 1 rotates continuously at a certain controlled speed. The charging of pellets by means of the fuel charge feeding screw 212 in the fuel charge unit 200 is increased and in proportion thereto also the amount of combustion air that is blown in by the fan 27 per unit of time so that the burner 1 in each power level will generate the intended power. The fuel charge feeding screw 212, however, is still being rotated intermittently but with shorter and shorter breaks between the fuel charging pulses at each higher power level. The feeding-in screw 40 at all the power levels E3-E8 goes on rotating continuously at a constant speed in order to provide the desired even inflow of pellets into the burner.

[0030] The power escalating procedure proceeds by shifting level E3 to level E4, then to level E5 etc., wherein each level has a duration which is pre-set in the program, e.g. 2 minutes. This stepwise escalation of generated power from the burner proceeds until the pre-set temperature of the water in the hot water conduit 42 is achieved, e.g. 80°C. If this occurs e.g. at power level E7, at which the generated power according to the example is 85 kW, and if the desired accuracy is pre-set in the control unit 300 to be $\pm 2^\circ\text{C}$, the following will take place if the temperature of the water in the hot water conduit 302 would rise to 82°C: the feeding of fuel charges by means of the fuel charge feeding unit 200, as well as the rotation rate of the drum 1, is immediately shifted down to the values which apply for next lower power level, in this case for power level E6, while the fan 207 continues to blow in combustion air into the combustion chamber 13 according to the program for power level E7. The fan continues to blow in excess combustion air until the excess fuel in the burner has been burned off, so that the remaining amount of fuel in the burner/drum will correspond with the conditions during power level E6. This after-blow-period, suitably 1-5 min, preferably ca 2 min, is programmed in the computer in the control

unit 300 to eliminate the risk of pyrolytic gases (risk of explosion) appearing, which thus can happen if an insufficient amount of oxygen is added. Thereafter the rotational rate of the fan 27 is reduced to the normal rotational rate for power level E6. The burner now proceeds to work on power level E6 according to the pre-set program. This goes on as long as the temperature is maintained on $80 \pm 2^\circ\text{C}$. During normal conditions, when the changes as far as environmental temperature the consumption of hot water, etc. are concerned, are not significant, the temperature gradually will drop to 78°C . Then it is immediately, or with a certain delay in order to avoid oscillations in the system, which can be difficult to control, shifted back to power level E7. In this way the combustion apparatus can be caused to oscillate between two power levels in a controlled mode. Therefore, because it is possible to operate at a plurality of different power levels, including delays between the power levels, there will be no big jumps in the function. The system therefore can be referred to as modulating, since it all the time is adapted to the power need in the building where the combustion apparatus is located.

[0031] If, at this stage, the measuring device 408 in the flue gas pipe 407 should transmit that the residual oxygen content not is within a preset value, e.g. transmits that the residual oxygen content (e.g. through measuring the CO_2 content) is too high, this will be transmitted to the control unit 300, the processor 308 making sure that an automatic regulation, according to the invention, will be performed with the purpose to re-establish optimal residual oxygen content and by that optimal efficiency of the combustion. As commonly known to a professional man in the field, it is a good approximation to use the knowledge that a burned oxygen molecule leads to ca 1 carbon dioxide molecule. Further, is valid that the oxygen content in air normally is ca 21 %. For security reasons the apparatus should be set to use maximum 20 of the 21 parts of oxygen supplied. Thus, it is possible to measure said usage the other way - through measuring the carbon dioxide. According to most facilities known today, it is quite sufficient that the residual oxygen content is at ca 5 %. As shown in Fig. 4 the pulse for fuel feeding-in will be increased to compensate a reduction of CO_2 -content (increased residual oxygen content) measured by the measuring device 408. To avoid overcompensating, which, in the worst scenario, would lead to an explosion, the increase of the feeding-in time will be performed with relatively small regulation steps. Preferably, the increase is performed with steps of maximally 10 %, more preferred, an increase of ca 2-6 %, in this case meaning an increase of the operating time for the fuel charge feeding screw 211, of between 0.1 and 0.3 s. Thus, this leads to an additional supply of fuel without changing any other variables, thus, a constant amount of air is supplied. After a certain, desired time interval, suitably 2 min, a new message of the residual oxygen content is transmitted by the measuring device 408, and if by that

time the set value not yet is achieved, another change, of the same size, of the operating time of the fuel charge feeding screw 211 will be performed. It shall be realized that instead of using percentages demanding a continuously calculating function of the processor, fixed, smaller units of steps may be used, e.g. steps of 0.1 s, to, during certain circumstances, possibly simplify the system. Thus, this regulation will proceed until the measuring device 408 signals that the residual oxygen content is within a desired set value. Suitably, this set value is an interval, which, considering the residual oxygen content, preferably is 4 % - 9 %. Certain burners, with large scope of power, may well be adjusted at different set values within different power intervals, e.g. a first set value (e.g. maximally 6 %) for the lower power ranges (2-30 of P_{max}), a somewhat lower set value (i.e. 5 %) at the intermediate power ranges (30-60 % of P_{max}) and an even lower set value (e.g. 4 %) for the highest power levels.

[0032] In Fig. 5 is shown a reversed situation compared with what is shown in Fig. 4. Namely, there is shown a situation where a new charge of fuel has been fed having a higher combustion value than the previously fed combustion charges. That emanates is a higher amount of oxygen being used than in the previous charge leading to a higher content of CO_2 in the flue gases. As a consequence of this, the measuring device 408 (when the flue gases have reached it) will signal that the content of CO_2 is too high, i.e. the residual content of oxygen is too low. Since such an erroneous situation means a possible risk of explosion, the regulating system should be designed to perform a larger change of regulation in this situation. When such a measure situation is transmitted, the control unit 300 will, as shown in Fig. 5, automatically reduce the operating time of the fuel charge feeding screw 211 with ca 15 %, i.e. in this case a reduction of the operating time with ca 0.8 s. As a result of this, in most cases, the amount of residual oxygen will increase drastically, since a large surplus of oxygen then is at hand. In connection to the next preset measuring, after ca 2 min, normally it will be seen that the residual oxygen level is above the interval of the set value, i.e. CO_2 is beneath the interval. Thus, the automatics will slowly compensate the residual oxygen value upwards, according to what is shown in Fig. 4, until again being within the set value. It is realized that during this adjustment of the residual oxygen content, suitably, the automatics is locked regarding power levels at one and the same power level, the control unit keeping the other values at one and the same level.

[0033] The invention is not limited to the above showed but may be varied within the scope of the following claims. The skilled man realizes that the invention may be used together with many different apparatuses for solid fuel that may strongly differ from the preferred example above. Thus, it is realized that the invention not is depending on specific details of e.g. the burner, the feeding-in channels for air etc.

Claims

1. A method for automatized combustion of solid fuel in a combustion apparatus which comprises a burner (1) which is connected to a boiler (400) and has a feeding-in opening (63, 62) for fuel and an outlet opening (3) which opens in a combustion chamber (401) inside the boiler which comprises a convection unit (402) and a flue gas pipe (407) for waste flue gases containing CO₂ and not combusted O₂, the combustion apparatus comprising a device (27) for feeding combustion air into the burner, and a fuel charge feeder (200, 212) for fuel provided to be driven by a motor (211), here called fuel charge feeding motor, the operation of the fuel charge feeding motor (211) being controlled by commands from a control unit (300) in dependency on measured values transmitted to the control unit (300) and in dependency on the heat power the burner shall generate, and a measuring device (408) arranged for measuring the content of CO₂ and/or O₂ in the flue gases, said measuring device (408) transmitting a measuring signal to said control unit (300) regarding the contents of the flue gas, the contents of the flue gas being regulated by means of the control unit (300) regulating the fuel charge feeding motor dependent upon the measured values of the flue gases, wherein the combustion air supply is kept essentially constant during the period of time when the control of the contents of the flue gas is being performed, **characterized in that** the fuel charge feeding motor (211) works intermittently and drivers the fuel in the form of charges to the burner (1) and that, if the measuring signal from the measuring device (408) regarding the contents of the flue gases is beyond a set value, the control unit (300) influences the operating time of the fuel charge feeding motor (211) in dependency on the value of the measuring signal, the operating time being either increased or reduced to adjust the contents of the flue gas at a desired set value, maintaining an optimal content of the gas as measured by the measuring device (408) in the flue gas pipe (407).
2. A method according to claim 1, **characterized in that** a larger change of the operating time of the fuel charge feeding motor is performed if the residual oxygen content of the flue gases is below the set value than if the residual oxygen content is above the set value.
3. A method according to claim 1, **characterized in that** the air supply is provided for by means of a fan (27) driven by a motor (22), the rotation rate of said motor (22) is kept at a constant level during said regulation of the flue gas contents.
4. A method according to claim 2, **characterized in that** a certain time interval (T) is allowed to pass after the change of the operating time of the fuel charge feeding motor (211) has been performed, before a possible additional adjustment is performed, in order to await a necessary time delay with the purpose of seeing the effect of the latest performed change, the time interval (T) being preferably between 30 s and 5 min, more preferred over 1 min.
5. A method according to claim 4, **characterized in that** the regulation change of the length of pulses of the fuel charge feeding motor (211) being at least twice greater at an adjustment downwards than at an adjustment upwards.
6. A method according to claim 1, **characterized in that** at least the major part of the motors (34, 22, 211) included in the combustion apparatus, preferably a stirring motor (34), an fan motor (22) and a fuel charge feeding motor (211) are provided to be rotated according to a number of different programs corresponding to the same number of different power levels, which are divided between a lowest power level (E1) for keep-alive burning and a top power level (E8).
7. A method according to claim 6, **characterized in that** the temperature of the water in a hot water conduit (403) is transmitted to the control unit (300) for automatic choosing of power level.
8. A method according to any of the claims above, **characterized in that** the fuel charge feeder (200, 212) by means of the fuel charge feeding motor (211) charges the fuel to a feeding-in device working in a more continuous mode than the fuel charge feeder and to distributing the charged fuel so that it is fed into the burner as an evened out flow.
9. A method according to any of the claims above, **characterized in that** different set values are used at different power ranges, a lower set value for the residual oxygen content, or reverse for CO₂, is used at higher power, ranges than at lower power ranges.
10. A method according to claim 9, **characterized in that** the change of the set value from the lowest power range to the highest power range is within 10-300 %, the change preferably exceeding 30 %.

Patentansprüche

1. Verfahren zum automatisierten Verbrennen eines Festbrennstoffs in einer Verbrennungsvorrichtung mit einem Brenner (1), der mit einem Kessel (400) verbunden ist und eine Zufuhröffnung (63, 62) für

Brennstoff sowie eine Auslassöffnung (3) hat, die in eine Verbrennungskammer (401) innerhalb des Kessels mündet, der eine Konvektionseinheit (402) und ein Abgasrohr (407) für abfallende Rauchgase, die CO₂ und nicht verbrannten O₂ enthalten, umfasst, wobei die Verbrennungsvorrichtung eine Vorrichtung (27) enthält, die dem Brenner Verbrennungsluft zuführt, und eine von einem Motor (211) angetriebene Zufuhrvorrichtung (200, 212) für die Brennstoffzufuhr, hier als Brennstoffzufuhrmotor bezeichnet, wobei der Betrieb des Brennstoffzufuhrmotors (211) über Befehle von einer Steuereinheit (300) gesteuert wird und zwar in Abhängigkeit von den an die Steuereinheit (300) gesendeten Messwerten und in Abhängigkeit von der Heizkraft, die von dem Brenner erzeugt werden soll, und mit einer Messvorrichtung (408), um den CO₂-Gehalt und/oder den O₂-Gehalt in den Rauchgasen zu messen, wobei die Messvorrichtung ein Messsignal über den Anteil an Rauchgas an die Steuereinheit (300) sendet, wobei der Rauchgasgehalt mithilfe der Steuereinheit (300) geregelt wird, die wiederum den Brennstoffzufuhrmotor in Abhängigkeit von den Rauchgasmesswerten einstellt, in dem die Zufuhr von Verbrennungsluft während der Zeit, in der der Rauchgasgehalt eingestellt wird, im Wesentlichen konstant gehalten wird, **dadurch gekennzeichnet, dass** der Brennstoffzufuhrmotor (211) intermittierend arbeitet und den Brennstoff in Form von Füllungen an den Brenner (1) liefert und dass, wenn das den Rauchgasgehalt betreffende Messsignal von der Messvorrichtung (408) einen Sollwert überschreitet, die Steuereinheit (300) die Betriebszeit des Brennstoffzufuhrmotors (211), abhängig von dem Wert des Messsignals, beeinflusst und die Betriebszeit zum Einstellen des Rauchgasgehalts bis zu einem Sollwert verlängert oder verkürzt, wobei ein optimaler von der Messvorrichtung (408) in dem Abgasrohr (407) gemessener Gasgehalt beibehalten wird.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** eine Änderung der Betriebszeit des Brennstoffzufuhrmotors deutlicher ausfällt, wenn der Gehalt an Restsauerstoff in den Rauchgasen den Sollwert unterschreitet, als wenn der Gehalt an Restsauerstoff den Sollwert überschreitet.
3. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** ein von einem Motor (22) angetriebenes Gebläse (27) für die Luftzufuhr sorgt, wobei die Drehgeschwindigkeit dieses Motors (22) während der Einstellung des Rauchgasgehalts auf konstantem Niveau gehalten wird.
4. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass**, nach Änderung der Betriebszeit

des Brennstoffzufuhrmotors (211), ein bestimmtes Zeitintervall (T) verstreichen darf, bevor eine mögliche zusätzliche Anpassung erfolgt, wobei eine notwendige Zeitverzögerung abzuwarten ist, um den Effekt der zuletzt durchgeführten Änderung zu sehen, und das Zeitintervall (T) vorzugsweise zwischen 30 Sekunden und 5 Minuten, noch vorteilhafter über 1 Minute, liegt.

5. Verfahren nach Anspruch 4, **dadurch gekennzeichnet, dass** der Änderungsbetrag bei den Impulslängen des Brennstoffzufuhrmotors (211) bei einer Anpassung nach unten wenigstens doppelt so groß ist wie bei einer Anpassung nach oben.
6. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** zumindest der Hauptteil der in der Verbrennungsvorrichtung enthaltenen Motoren (34, 22, 211), vorzugsweise ein Rührmotor (34), ein Gebläsemotor (22) und ein Brennstoffzufuhrmotor (211), zum Rotieren gemäß einer Anzahl verschiedener Programme vorgesehen ist, die derselben Anzahl verschiedener Leistungsstufen entsprechen, die wiederum zwischen einer niedrigsten Leistungsstufe (E1) zur Aufrechterhaltung des Brennvorganges und einer höchsten Leistungsstufe (E8) liegen.
7. Verfahren nach Anspruch 6, **dadurch gekennzeichnet, dass** die Temperatur des Wassers in einer Heißwasserleitung (403) an die Steuereinheit (300) gesendet wird, um eine Leistungsstufe automatisch auszuwählen.
8. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Brennstoffzufuhrmotor (211) mithilfe des Brennstoffzufuhrmotors (211) den Brennstoff in eine Einfüllvorrichtung füllt, die kontinuierlicher als die Brennstoffzufuhr arbeitet, und um den eingefüllten Brennstoff zu verteilen, so dass er als gleichmäßiger Ausfluss in den Brenner eingeführt wird.
9. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** unterschiedliche Sollwerte in unterschiedlichen Leistungsbereichen verwendet werden, wobei ein niedriger Sollwert für den Gehalt an Restsauerstoff, oder umgekehrt für CO₂, in höheren Leistungsbereichen als in niedrigeren Leistungsbereichen verwendet wird.
10. Verfahren nach Anspruch 9, **dadurch gekennzeichnet, dass** die Änderung des Sollwerts vom niedrigsten Leistungsbereich in den höchsten Leistungsbereich zwischen 10 - 300 % liegt, wobei die Änderung vorteilhafterweise 30 % übersteigt.

Revendications

1. Procédé pour la combustion automatisée d'un combustible solide dans un appareil de combustion qui comprend un brûleur (1) qui est relié à une chaudière (400) et comporte une ouverture d'introduction (63, 62) pour le combustible et une ouverture de sortie (3) qui s'ouvre dans une chambre de combustion (401) à l'intérieur de la chaudière, qui comprend une unité de convection (402) et un tuyau de gaz de combustion (407) pour les gaz déchets de combustion contenant du CO₂ et du O₂ n'ayant pas brûlé, l'appareil de combustion comprenant un dispositif (27) destiné à introduire de l'air de combustion dans le brûleur, et un dispositif d'alimentation de charge combustible (200, 212) pour du combustible prévu pour être entraîné par un moteur (211), appelé ici moteur d'alimentation de charge combustible, le fonctionnement du moteur d'alimentation de charge combustible (211) étant commandé par des ordres provenant d'une unité de commande (300) en fonction de valeurs mesurées transmises à l'unité de commande (300) et en fonction de la puissance de chauffage que le brûleur devra générer, et un dispositif de mesure (408) agencé pour mesurer la teneur en CO₂ et/ou en O₂ dans les gaz de combustion, ledit dispositif de mesure (408) transmettant un signal de mesure à ladite unité de commande (300) concernant les teneurs en gaz de combustion, les teneurs en gaz de combustion étant régulées au moyen de l'unité de commande (300) régulant le moteur d'alimentation de charge combustible en fonction des valeurs mesurées des gaz de combustion, dans lequel l'alimentation en air de combustion est maintenue sensiblement constante pendant la période pendant laquelle la commande des teneurs en gaz de combustion est effectuée, **caractérisé en ce que** le moteur d'alimentation de charge combustible (211) fonctionne de manière intermittente et délivre le combustible sous la forme de charges au brûleur (1) et que, si le signal de mesure provenant du dispositif de mesure (408) concernant les teneurs de gaz de combustion se situe au-delà d'une valeur de consigne, l'unité de commande (300) influence le temps de fonctionnement du moteur d'alimentation de charge combustible (211) en fonction de la valeur du signal de mesure, le temps de fonctionnement étant soit accru, soit réduit pour ajuster les teneurs du gaz de combustion à une valeur de consigne souhaitée, maintenant une teneur optimale du gaz tel que mesuré par le dispositif de mesure (408) dans le tuyau de gaz de combustion (407).
2. Procédé selon la revendication 1, **caractérisé en ce qu'un** plus grand changement du temps de fonctionnement du moteur d'alimentation de charge combustible est effectué si la teneur en oxygène ré-

siduel des gaz de combustion se situe en dessous de la valeur de consigne que si la teneur en oxygène résiduel se situe au-dessus de la valeur de consigne.

3. Procédé selon la revendication 1, **caractérisé en ce que** l'alimentation en air est fournie au moyen d'un ventilateur (27) entraîné par un moteur (22), la vitesse de rotation dudit moteur (22) est maintenue à un niveau constant pendant ladite régulation des teneurs en gaz de combustion.
4. Procédé selon la revendication 2, **caractérisé en ce qu'on** laisse passer un certain intervalle de temps (T) après que le changement du temps de fonctionnement du moteur d'alimentation de charge combustible (211) a été effectué, avant qu'un ajustement additionnel possible soit effectué, afin d'attendre un délai de temps nécessaire dans le but d'observer l'effet du dernier changement effectué, l'intervalle de temps (T) étant de préférence compris entre 30 s et 5 min, de manière davantage préférée au-dessus de 1 min.
5. Procédé selon la revendication 4, **caractérisé en ce que** le changement de régulation de la longueur des impulsions du moteur d'alimentation de charge combustible (211) est au moins deux fois plus grand à un ajustement vers le bas qu'à un ajustement vers le haut.
6. Procédé selon la revendication 1, **caractérisé en ce qu'au** moins la majeure partie des moteurs (34, 22, 211) inclus dans l'appareil de combustion, de préférence un moteur d'agitation (34), un moteur de ventilateur (22) et un moteur d'alimentation de charge combustible (211) sont prévus pour être mis en rotation selon un nombre de programmes différents correspondant au même nombre de différents niveaux de puissance, qui sont divisés entre un niveau de puissance le plus bas (E1) pour maintenir un brûlage et un niveau de puissance supérieur (E8).
7. Procédé selon la revendication 6, **caractérisé en ce que** la température de l'eau dans un conduit d'eau chaude (403) est transmise à l'unité de commande (300) pour un choix automatique du niveau de puissance.
8. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le dispositif d'alimentation de charge combustible (200, 212) au moyen du moteur d'alimentation de charge combustible (211) charge le combustible dans un dispositif d'introduction fonctionnant dans un mode plus continu que le dispositif d'alimentation de charge combustible et pour distribuer le combustible char-

gé de sorte qu'il est introduit dans le brûleur sous forme d'écoulement uniformisé.

9. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** différentes valeurs de consigne sont utilisées à différentes gammes de puissance, une valeur de consigne inférieure pour la teneur en oxygène résiduel, ou inverse pour le CO₂, est utilisée à des gammes de puissance supérieures qu'à des gammes de puissance inférieures. 5 10
10. Procédé selon la revendication 9, **caractérisé en ce que** le changement de la valeur de consigne allant de la gamme de puissance la plus basse à la gamme de puissance la plus élevée se situe dans l'intervalle de 10 à 300 %, le changement excédant de préférence 30 %. 15

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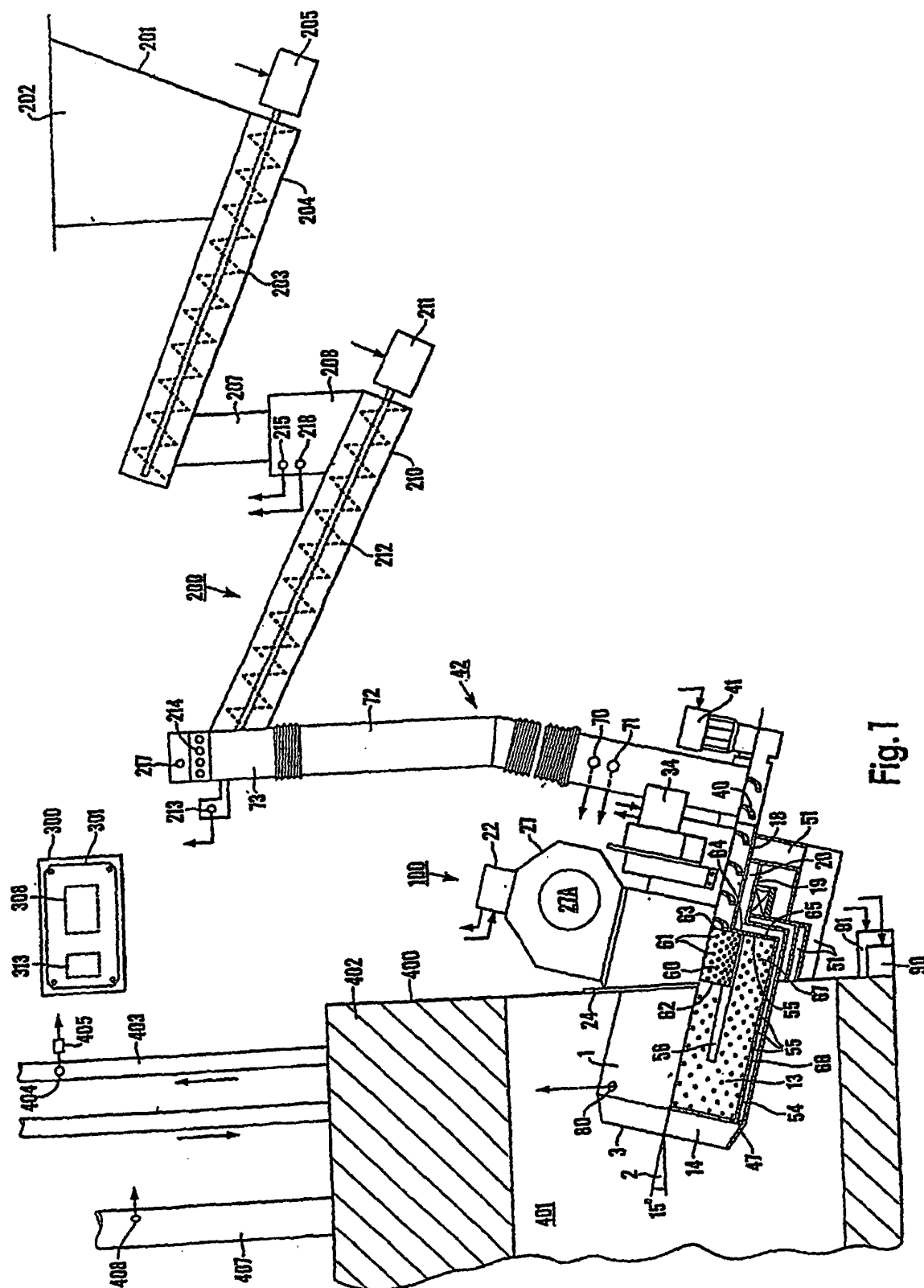
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EFFECT LEVEL E2

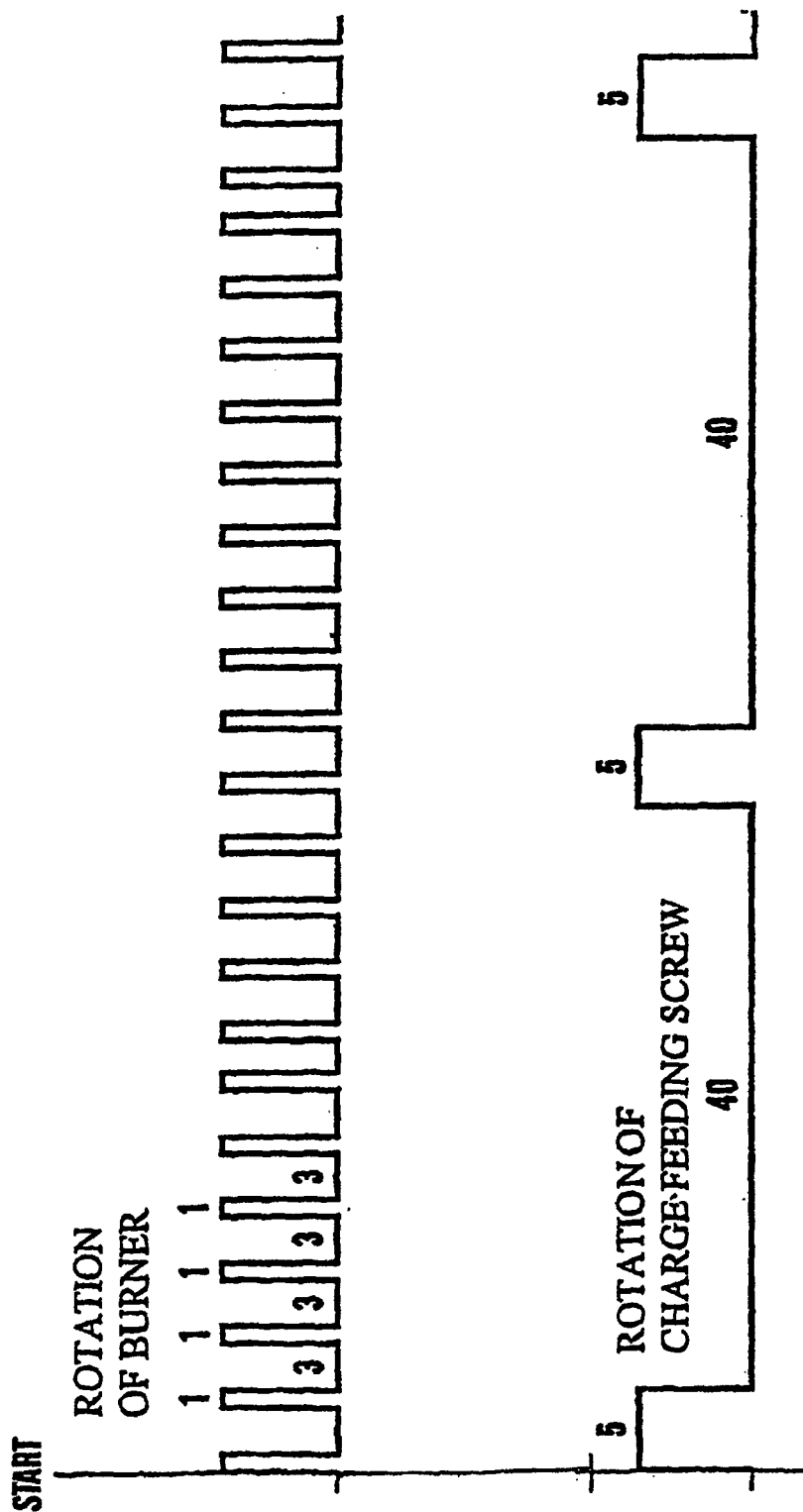


Fig. 2

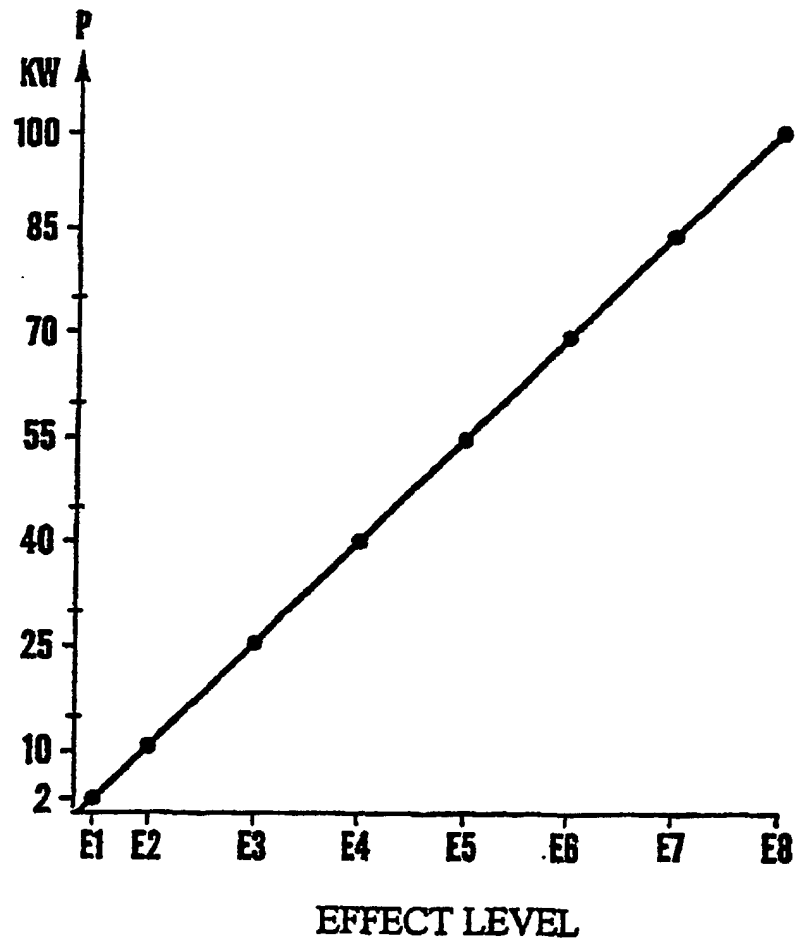


Fig.3

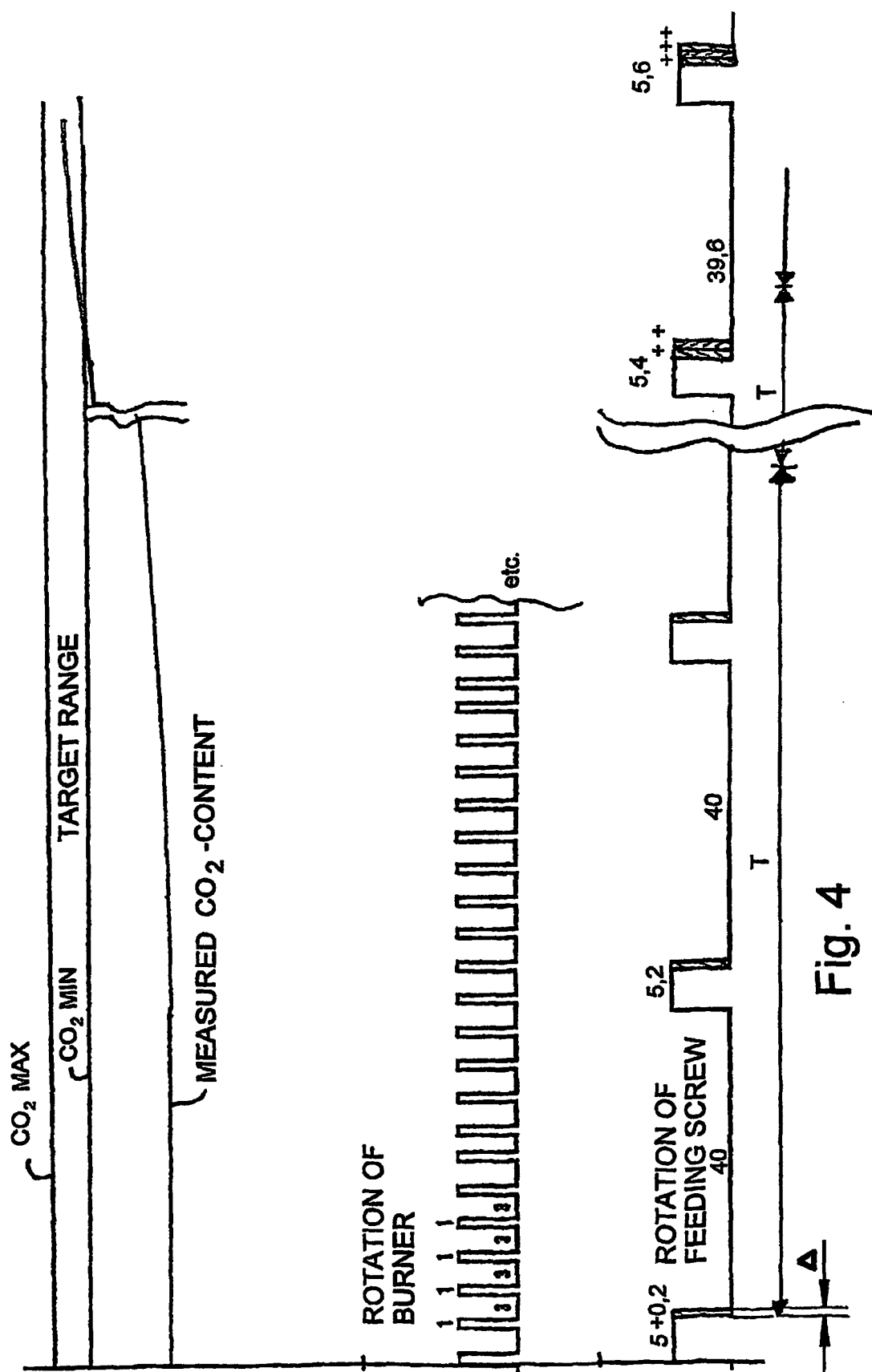


Fig. 4

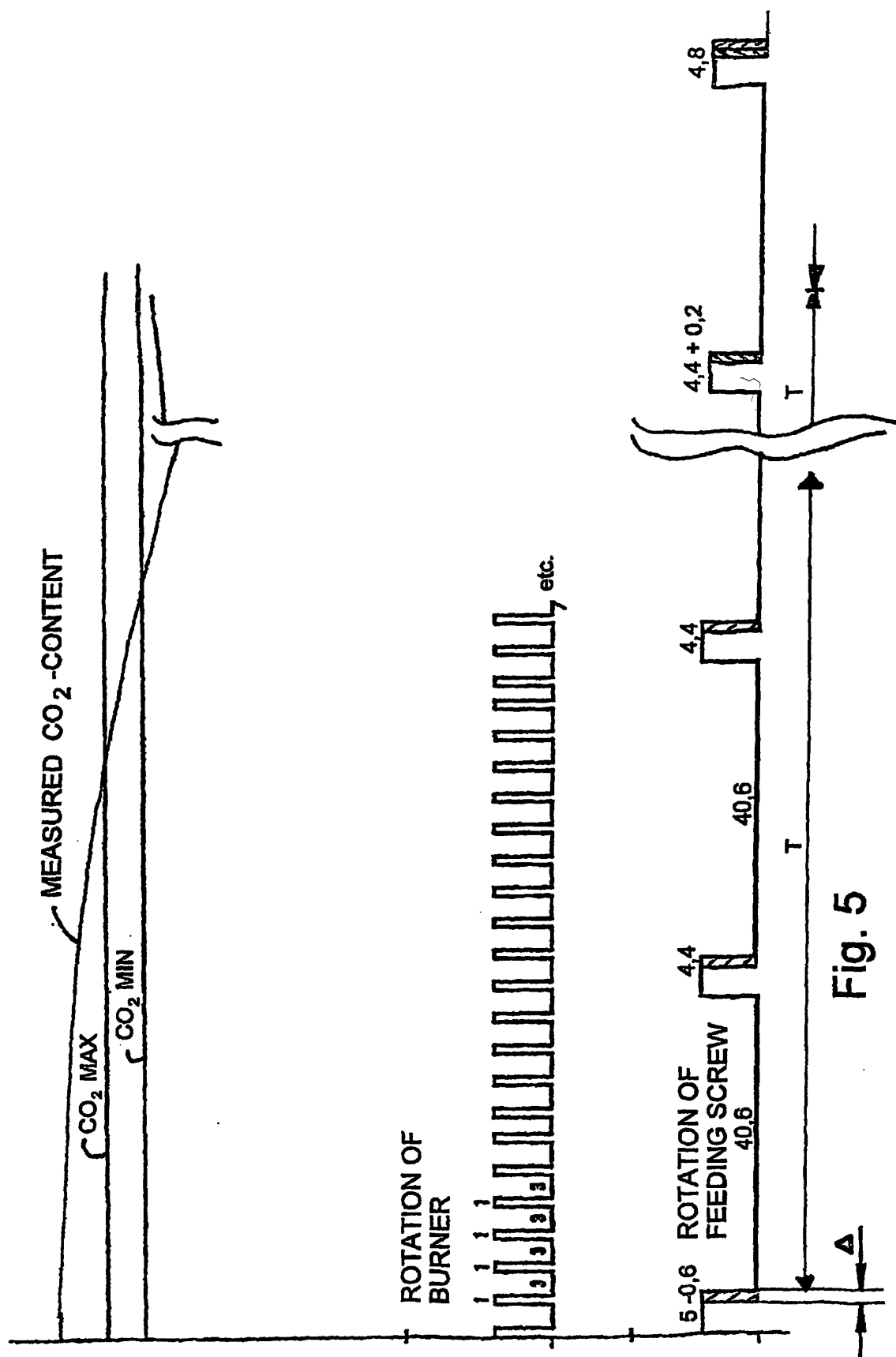


Fig. 5