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(71) Applicant: **BURMEISTER & WAIN ENERGI A/S**
DK-2830 VIRUM (DK)

(72) Inventor: **Johnsen, Joergen Boegild**
2860 Soeborg (DK)

(74) Representative: **Jessen, Ivar Bergishagen et al**
c/o Internationalt Patent-Bureau
Hoeje Taastrup Boulevard 23
2630 Taastrup (DK)

(54) **A process for controlling the combustion in a boiler having a vibrating grate**

(57) By the process the supplied amounts of primary air and/or fuel are reduced in a definite way under and shortly after the vibration of the vibrating grate, whereby a sudden increase of the combustion rate caused by the

vibration is avoided. As a result the sudden drops of the oxygen content of the exhaust gas occurring in common boilers are avoided, said drops being caused by the fact that the common fuel control reacts too slowly on sudden changes in the combustion conditions.

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Description

The invention relates to a process for controlling the combustion in a boiler having a vibrating grate which is vibrated for a short period and left to rest for a substantially longer period of time, wherein primary air is supplied to the underside of the grate and flows up through openings therein, wherein secondary air is supplied through nozzles provided on at least one boiler wall and the fuel is spread onto the grate through a feed opening in at least one boiler wall, and wherein the supplied amount of primary air and/or amount of fuel supplied are determined dependent on the result of current measurements of one or more of the boiler state variables and parameters which reflect the air surplus and the heat absorption.

Known boilers of this type are i.a. used for burning wood chips, wood waste, sawdust, and the like materials or mixtures thereof, but may be used for burning nearly all types of solid fuel which may be spread onto the grate.

The grate is vibrated periodically, typically for approx. 2-5 seconds with a frequency of 5-8 Hz and an amplitude of approx. 7-10 mm followed by a standstill period of 5-30 minutes. The grate may tilt 7-10° towards a cinder pit and vibration may typically take place in a direction tilting at an angle of 10-18° reversely to the tilting of the grate.

The object of the vibration is to distribute the fuel positioned on the grate over its surface and to convey ash from the combustion to the cinder pit. By vibration of the grate a change of the immediate consumption of fuel on the grate occurs, and in the known boilers, where a high amount of primary air is used, the combustion rate increases. The effect on the consumption of fuel on the grate is significant in 2-5 minutes after the vibration. Furthermore, the vibration of the grate causes a part of flammable material to be whirled up from the grate and to burn in the combustion chamber for a period of 3-10 seconds after the vibration.

Such sudden increases in the combustion rate will, if no precautions are taken, lead to a drop in the oxygen content of the exhaust gas and consequently to emission of big amounts of CO and other polluting products stemming from a partial combustion. The control of the combustion in known boilers is based on the fact that the oxygen content of the exhaust gas and the value of one or more parameters which reflects the heat absorption in the boiler, is measured currently and that the amount of primary air supplied, fuel and secondary air is adapted relative thereto. This way of regulating suffers from the drawback that the measurements reflect the immediate conditions with a time lag of typically one minute, and it is therefore not possible for the control system to take the abovementioned quick increase in the rate of combustion into account, which increase occurs by the vibration of the grate.

The increase of the rate of combustion entails a

quick increase in the heat release and in the oxygen need, which results in a drop of the oxygen content in the exhaust gas, and as a consequence hereof emission of big amounts of CO and other polluting products stemming from a partial combustion. To prevent this an air surplus of around 30% relative to what is stoichiometrically required is used in such boilers.

The object of the invention is to provide a process of the type mentioned by way of introduction, by means of which the immediate heat release is kept approximately constant, sudden drops in the oxygen content of the exhaust gas being simultaneously avoided. This object is according to the invention met in that the supplied amount of primary air and/or amount of fuel in connection with each vibration further is reduced relative to the amount determined by the current measurement, that the reduction is initiated immediately prior to the vibration reaching its maximum frequency and is reduced after the end of the vibration to reach substantially the level before the reduction in such a way that the sum of the reduction per cent of the amount of primary air supplied and the reduction per cent of the supplied amount of fuel, summed up separately as an average over five seconds in the major part of a period starting when the vibration has reached its maximum frequency and ending ninety seconds later, amount to at least 15%. If for instance the reduction per cent of the supplied amount of primary air, measured as stated, is 50% and the reduction per cent of the amount of fuel supplied, measured in the same way, is 80%, the sum of the reductions is 130%.

The process according to the invention utilizes the fact that two of the parameters having substantial influence on the combustion, viz. the supplied amount of primary air and the supplied amount of fuel, can be changed nearly instantaneously. Furthermore, the time for changing these parameters is determined on basis of the knowledge of the time for the starting of the vibration, and thereby the previously mentioned time lag in connection with the measurement of the oxygen content of the exhaust gas is avoided. By the process according to the invention the boiler is substantially controlled like known boilers, but this control is superimposed by a control of the immediately supplied amount of primary air and/or amount of fuel, which is controlled on basis of the knowledge of the time for the vibration.

Hereby is obtained that variations in the oxygen content of the exhaust gas can be limited, and that the average air surplus consequently can be reduced, the instantaneous heat release being simultaneously kept approximately constant. A total effect is that also a stable operation is obtained, which i.a. has the advantage of making further improvements of the combustion possible, improvements which would not otherwise be possible.

The substantial advantages obtained by the process according to the invention is that the air surplus becomes smaller, which entails a smaller production of

NO, a smaller energy consumption for pressurizing combustion air and for sucking exhaust gases through the boiler and a smaller loss of heat on account of the exhaust gas of the boiler.

It is a further, substantial advantage that the process according to the invention allows the load on the grate, compared to known boilers, to be substantially increased. It has turned out that in known boilers there is in practice an upper limit to the load about 2MW/m². Is the load to be increased more than that, it is necessary either to increase the amount of primary air or to utilize the amount of primary air better than before.

If the choice taken is to increase the amount of primary air, other problems arise, first and foremost that possible unburnt particles are blown up into the combustion chamber.

Is the choice on the contrary to increase the thickness of the layer of fuel in order to create an intimate contact between the primary air and the fuel with a view to avoiding increase of the amount of primary air, there will at each vibration occur such a heavy drop in the oxygen content of the exhaust gas and of the heat release, that the combustion cannot be kept under control by the usual control system of the boiler, which results in an unstable operation.

According to the invention a process has now been provided for controlling the combustion in a boiler which has the effect that such drops in oxygen content and in the heat release may be substantially reduced or completely eliminated. This opens up for the possibility of using boilers with a grate load which may be 10 - 15% higher than the loads used up till now.

A preferred embodiment of the invention is characteristic in that the amount of secondary air supplied is increased simultaneously with the reduction of the amount supplied of primary air and/or the supplied amount of fuel.

By counteracting the increased combustion rate during and after the vibration of the grate by reducing the supply of new fuel, the total amount of exhaust gas will decrease, due to a decrease of the development of water vapour due to drying of the fuel supplied. Correspondingly, a reduced amount of primary air will cause a reduction of the total amount of exhaust gas. By increasing the amount of secondary air a constant amount of exhaust gas may substantially be maintained. This results in a reduction of variations in heat absorption in the heat surfaces of the boiler, and variations of pressure and temperatures in the boiler are limited.

A second process according to the invention is characteristic in that in the determination of the size of said reduction of the amount supplied of primary air and/or amount of fuel under a given vibration use is made of the result of a measurement of at least one of the state variables of the boiler, while one of the immediately preceding vibrations influences substantially the value of the state variable.

The object is to ensure that the reduction of the sup-

plied amount of primary air and/or amount of fuel has the proper size in relation to the current operational condition. The result of measurements of the state variable of the boiler at preceding vibrations are part of an algorithm for determination of the size of the reduction at a succeeding vibration.

A third process according to the invention is characteristic in that said state variable is the oxygen content of the exhaust gas, and that the size of the reduction of the supplied amount of primary air and/or the fuel amount is increased when the measurement indicates a drop in the oxygen content of the exhaust gas in the period immediately after the vibration of the grate, and in that the size of the reduction is decreased when the result of the measurement indicates an increase of the oxygen content of the exhaust gas.

By measurement of the oxygen content in the exhaust gas the algorithm may comprise comparison of the oxygen content in the exhaust gas immediately before and 1-2 minutes after the vibration of the grate, where a drop of the oxygen content of more than 0.2% point has the effect that the reduction of the supplied amount of primary air and/or the supplied amount of fuel is increased by 20% and where an increase of the oxygen content in the exhaust gas by more than 0.2% point causes a decrease of said reduction by 20%.

A fourth embodiment is characteristic in that the reduction of the supplied amount of primary air at the starting of the vibration is 30% of the starting value, that the reduction of the supplied amount of fuel is decreased to 30% of the starting value five seconds after the vibration has stopped, and that the deviation per cent of each of said amounts from the starting value is decreased gradually such that it is halved each time two minutes have passed.

Hereby an even, asymptotical transition to the starting value before the vibration is obtained, which contributes to keeping the oxygen content in the exhaust gas constant. Whether it is the supplied amount of primary air or the amount of fuel, or a combination of both, which is reduced, is not decisive for the attainment of the desired effect. If a reduction of only one parameter takes place, this reduction should be more massive.

In a fifth embodiment of the process an air flow may be created above the grate in a direction away from the outlet edge of the grate at the cinder pit to the opposite end of the grate, which air flow in a sixth embodiment may be created by in-blowing of secondary air through secondary air nozzles which are placed in the boiler wall above the outlet edge of the grate and below the level of the feed opening for the fuel, which nozzles may be directed towards the surface of the grate in the area at the rear edge of the grate. Moreover, the centre line of each secondary air nozzle may be placed within a conical surface with its vertex in the nozzle and having a vertex angle of approx. 20°, the centre line of said cone being directed towards an intersection point between the surface of the grate and an imaginary, vertical line

starting from a point in the surface of a part of a boiler wall, said point being positioned at the same level as the nozzle and opposite thereto.

Hereby is obtained that a part of the flammable material, which on account of the vibration of the grate is whirled up therefrom, is carried to the area of the rear edge of the grate where it, on account of the deflection of the exhaust gas flow at the boiler wall at the rear edge of the grate, will be separated from the flow and fall back onto the grate, forming part of the fuel positioned on the grate and burning together with it instead of burning in the combustion chamber above the grate. Simultaneously, the gas flow absorbs and mixes primary air and degasification products from the grate and thereby ensures a massive combustion in the area above the grate, which ensures radiation back towards the grate.

In an eight embodiment of the process according to the invention the supplied amount of primary air is distributed over the grate in such a way that the amount of primary air per area unit, which is supplied through the main part of the third of the active area of the grate which is closest to the cinder pit, is bigger than the amount of primary air per area unit supplied through the whole active area of the grate, the active area being defined as the area of the smallest rectangle compassing all the openings of the grate.

By supplying an amount of primary air per area unit as stated above to the lower third of the grate, a massive combustion is obtained at the lowest part of the grate, with a high temperature particularly in the zone in which the fuel stops covering the openings for the primary air openings of the grate. This ensures a stable ignition of the exhaust gas flow across the grate.

The supply of secondary air to the secondary air nozzles may constitute between 1/4 and 1/8 of the amount of primary air at a pressure which at the maximum yield of the boiler typically is 6000 Pa. The spreading of the fuel is to be adapted such that approx. 2/3 of the fuel may be spread on the middle third of the grate, whereas 1/3 is spread on the upper third of the grate in such a way that the amount of fuel which reaches the rear part of the grate is practically nil.

By use of the above operational system it is possible to use very low amounts of primary air, typically 30% of primary air and 70% of secondary air by combustion of wood chips with a moisture content of 55%. With such low portions of primary air, with the above-mentioned distribution of primary air and the above-mentioned movement of the gas across the grate, it is possible to reduce the amount of fuel particles which is blown out at the top of the combustion chamber, to reduce the loss connected therewith and to reduce the amount of CO and other substances harmful to the environment and stemming from a partial combustion of these particles during the cooling of the exhaust gases.

The invention will now be described in detail in the following by means of the drawing, in which

Fig. 1 is a lateral view of a vertical section in the combustion chamber of a boiler for use in carrying out the process according to the invention, Figs. 2-5 are graphs showing operational parameters and state variables in a known boiler dependent on the time, viz. the vibration frequency of the grate, the supplied amount of fuel, the supplied amount of primary air and the O₂ content of the exhaust gas, and

Figs. 6-9 are graphs showing parameters and state variables like in Figs. 2-5, but for a boiler with which the process according to the invention is carried out.

The boiler has a combustion chamber 1 defined by a front wall 2 and a rear wall 3 and at the bottom it has a vibration grate 4. Under the grate there is an ash box 5, and at the end of the grate closest to the front wall there is a cinder pit 6. The fuel is supplied by means of a helical conveyor not shown to a duct 7, from which it slides to a spreader stoker, which spreads it onto the grate 4 through an opening in the front wall 8 by means of an injection nozzle 9, to which air is supplied from an air duct 10. The spreading of the fuel should be adapted such that approx. 2/3 of the fuel may be spread onto the middle third of the grate, whereas 1/3 is spread onto the upper third of the grate in such a way that the amount of fuel which reaches the rear part of the grate is approximately nil. An air nozzle 15 is provided under the opening 8 in the front wall, said nozzle being supplied with air from an air duct 16. The nozzles 15 are directed towards the rear edge of the grate and serve for mixing degassing products and primary air from the fuel on the vibration grate 4.

For the injection of secondary air the boiler is provided with several groups of secondary air nozzles. At the rear wall above the grate nozzles 17 and 19 are provided, which are supplied with air from air ducts 18 and 20, respectively. On the front wall and the rear wall oppositely positioned protrusions 25 and 26 are provided, said protrusions carrying secondary nozzles 30, 31, to which air is supplied from an air duct 32 and 33, 34, to which air is supplied from an air duct 35. The supply of secondary air to the secondary air nozzles may constitute between 1/4 and 1/8 of the amount of primary air at a pressure, which at the maximum yield of the boiler typically is 6000 Pa.

The vibration grate 4 is placed with a tilt of 7° relative to horizontal and with its highest point at the rear wall 3. For the flow of primary air the grate is typically provided with 1000 holes per m² with a diameter of 3-4 mm. The grate is vibrated by a vibration unit 11 with a frequency of approx. 9 Hz and an amplitude of ± 5 mm in a direction forming an angle of 13° with horizontal and directed reversely to the tilting of the grate. The vibration is carried out periodically, the grate being vibrated for approx. 2-5 seconds followed by a period of standstill of 5 - 20 minutes.

In order to illustrate the effect obtained by the proc-

ess according to the invention the combustion conditions of a known boiler will first be gone over in the following, as illustrated in Figs. 2-5, and then the corresponding conditions for a boiler for use in carrying out the process according to the invention, as illustrated in Figs. 6-9.

Fig. 2 shows how the frequency of the vibrations of the grate changes dependent on the time. In the left side of the figure the frequency course is shown over an axis of abscissas, which is divided into intervals of 10 seconds, whereas the axis of abscissas in the right side of the figure is divided into intervals of 1 minute. The same division of the axis is used in all the following figures and shall therefore not be mentioned in connection therewith.

It will be seen from Figs. 3 and 4 that the supplied amount of fuel and the supplied amount of primary air are regulated down within the first few minutes after the vibration of the grate has stopped, following which the regulation system of the boiler slowly increases said amounts to the values which they had before the starting of the vibration. The reason for this slow down-regulation appears from Fig. 5, which shows that the actual value of the oxygen content in the exhaust gas (the curve is given the reference a) drops abruptly due to the vibration of the grate, whereas the value measured by the conventional O_2 meters drops slower. It is due to the latter drop that the amount of primary air and the amount of fuel are regulated down, and the oxygen content in the exhaust gas again rises asymptotically to the level before the vibration.

Fig. 6 shows in the same way as Fig. 2 the frequency course of the vibrations of the grate, but for a boiler for use in carrying out the process according to the invention. Fig. 7 and 8 show that the supplied amount of fuel and the supplied amount of primary air, respectively, drop abruptly by the vibration, after which these amounts increase in a controlled way. In respect of the amount of primary air it is indicated in Fig. 8 that the original reduction of the supplied amount of primary air by 30%, indicated by the curve e, is approximately halved by each passing of 2 minutes. The curves shown in Figs. 7 and 8 marked d and f, respectively, indicate the value of the amounts of fuel and amounts of primary air, respectively, which is set by the regulation system of the boiler based on conventional O_2 measurement of the exhaust gas. The curves c and e, respectively, show the actually set amounts of fuel and amounts of primary air which are obtained by an additional regulation which is made on basis of the knowledge of the starting of the vibration.

In Fig. 9 the curve g shows the actual value of the oxygen content in the combustion chamber, whereas the curve h shows the value measured by means of a conventional O_2 meter. As will be seen a practically constant oxygen content in the exhaust gas is obtained as a consequence of the regulation of the supplied amounts of primary air and amounts of fuel. However,

as indicated by the reference i, a short increase of this O_2 value measured in a conventional way takes place.

5 Claims

1. A process for controlling the combustion in a boiler having a vibrating grate which is vibrated for a short period and left to rest for a substantially longer period of time, wherein primary air is supplied to the underside of the grate and flows up through openings therein, wherein secondary air is supplied through nozzles provided on at least one boiler wall and the fuel is spread onto the grate through a feed opening in at least one boiler wall, and wherein which the supplied amount of primary air and/or amount of fuel supplied are determined dependent on the result of current measurements of one or more of the boiler state variables and parameters which reflect the air surplus and the heat absorption, **characterized** in that the supplied amount of primary air and/or amount of fuel in connection with each vibration are further reduced relative to the amount determined by the current measurement, that the reduction is initiated immediately prior to the vibration reaching its maximum frequency and is reduced after the end of the vibration to reach substantially the level before the reduction in such a way that the sum of the reduction per cent of the amount of primary air supplied and the reduction per cent of the supplied amount of fuel, summed up separately as an average over five seconds in the major part of a period starting when the vibration has reached its maximum frequency and ending ninety seconds later, amount to at least 15%.
2. A process according to claim 1, **characterized** in that the amount of secondary air supplied is increased simultaneously with the reduction of the amount supplied of primary air and/or the supplied amount of fuel.
3. A process according to claims 1 or 2, **characterized** in that in the determination of the size of said reduction of the amount supplied of primary air and/or amount of fuel under a given vibration use is made of the result of a measurement of at least one of the state variables of the boiler, while one of the immediately preceding vibrations influences substantially the value of the state variable.
4. A process according to claim 3, **characterized** in that said state variable is the oxygen content of the exhaust gas, and that the size of the reduction of the supplied amount of primary air and/or the fuel amount is increased when the measurement indicates a drop in the oxygen con-

tent of the exhaust gas in the period immediately after the vibration of the grate, and in that the size of the reduction is decreased when the result of the measurement indicates an increase of the oxygen content of the exhaust gas.

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5. A process according to any of the preceding claims, **characterized** in that the reduction of the supplied amount of primary air at the starting of the vibration is 30% of the starting value, that the reduction of the supplied amount of fuel is decreased to 30% of the starting value five seconds after the vibration has stopped, and that the deviation per cent of each of said amounts from the starting value is decreased gradually such that it is halved each time two minutes have passed. 10 15

6. A process according to any of the preceding claims, **characterized** in that an air flow is created above the grate in a direction away from the outlet edge of the grate at the cinder pit to the opposite end of the grate. 20

7. A process according to claim 6, **characterized** in that the air flow is created by in-blowing of secondary air through secondary air nozzles which are placed in the boiler wall above the outlet edge of the grate and below the level of the feed opening for the fuel, and in that the nozzles are directed towards the surface of the grate in the area at the rear edge of the grate. 25 30

8. A process according to claim 7, **characterized** in that the centre line of each secondary air nozzle is placed within a conical surface with vertex in the nozzle and having a vertex angle of approx. 20°, the centre line of said cone being directed towards an intersection point between the surface of the grate and an imaginary, vertical line starting from a point in the surface of a part of a boiler wall, said point being positioned at the same level as the nozzle and opposite thereto. 35 40

9. A process according to claims 6 - 8, **characterized** in that the supplied amount of primary air is distributed over the grate in such a way that the amount of primary air per area unit, which is supplied through the main part of the third of the active area of the grate which is closest to the cinder pit, is bigger than the amount of primary air per area unit supplied through the whole active area of the grate, the active area being defined as the area of the smallest rectangle compassing all the openings of the grate. 45 50 55

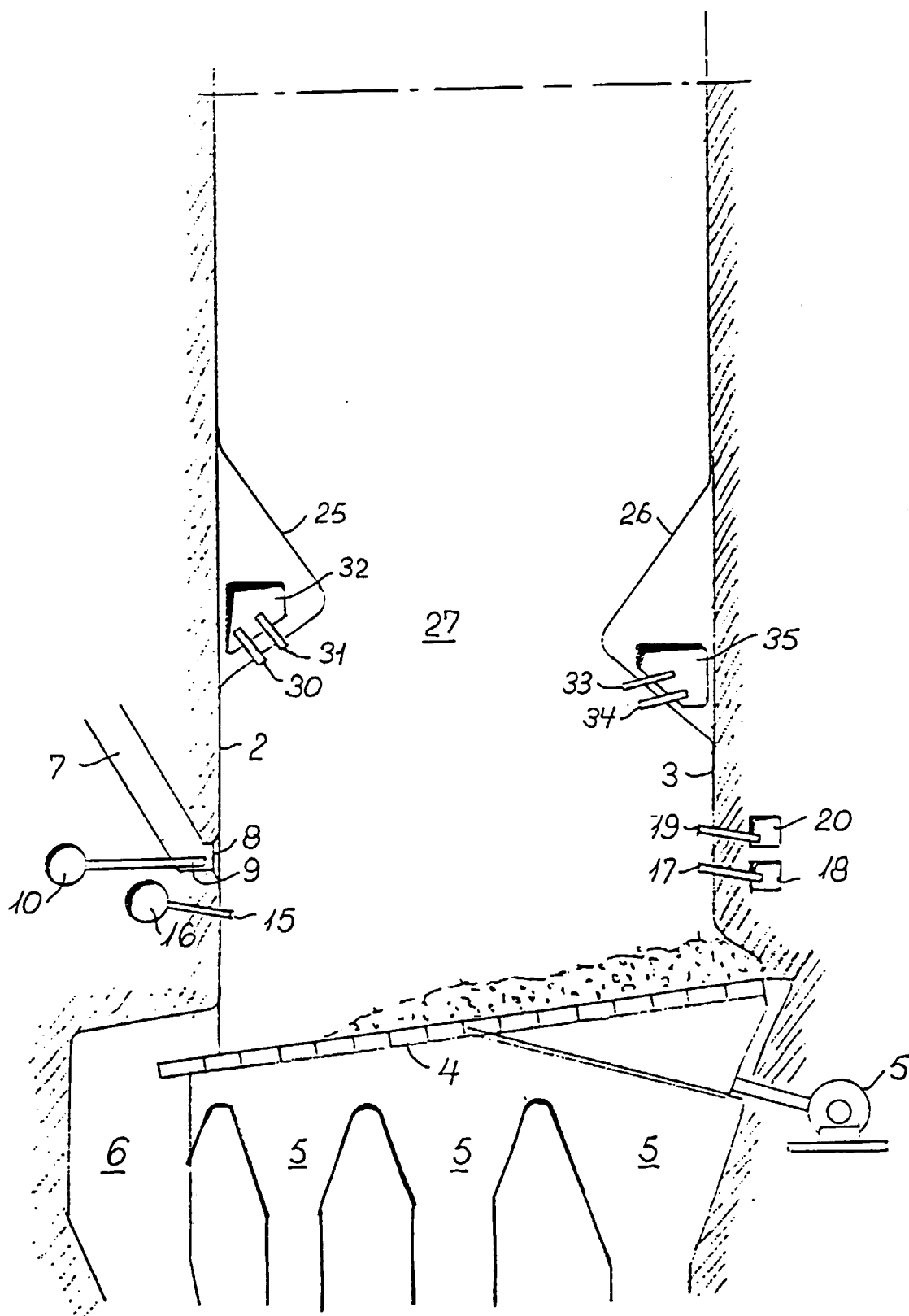


FIG. 1

