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

(11) EP 3 734 158 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.11.2020 Bulletin 2020/45

(51) Int Cl.:
F23J 7/00 *(2006.01)* ***F23C 9/00*** *(2006.01)*

(21) Application number: **20020236.4**

(22) Date of filing: **19.05.2020**

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

(30) Priority: **21.03.2019 PL 42934319**

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(54) **METHOD FOR THE REDUCTION OF NITROGEN OXIDES AND CARBON MONOXIDE IN THE FURNACE CHAMBERS OF WATER AND STEAM BOILERS, PARTICULARLY GRATE BOILERS AND A SYSTEM FOR THE REDUCTION OF NITROGEN OXIDES AND CARBON MONOXIDE IN THE FURNACE CHAMBERS OF WATER AND STEAM BOILERS, PARTICULARLY GRATE BOILERS**

(57) **Summary**

A method of limiting the formation and/or reduction of nitrogen oxides by injecting process gas into the furnace chamber in the opposite direction to the main direction of the flue gas flowing through the furnace chamber, or in another version, process gas with a reagent is injected at a rate of 30 to 180 m/s, preferably 135 m/s, the injection points being located on the front screen of the furnace chamber, on the rear screen of the furnace chamber, on the upper screen of the furnace chamber and on the side screens of the furnace chamber.

A system for the realization of the method according to the invention for NOx reduction includes process gas injection lances (6), (10), (12), (16), reagent injection lances (7), (13), (17), furnace chamber (4), process gas intake (18), process gas fan (21), a measuring system mounted on the process gas collector (22), control and cut-off components installed on the process gas collector (23), a reagent tank (24), a reagent pump (25), measuring systems (26) mounted on the reagent installation, control and cut-off elements (27) installed on the reagent installation, a central lance for reagent injection into process gas (28), a device measuring exhaust gas composition (29) and a controller (30).

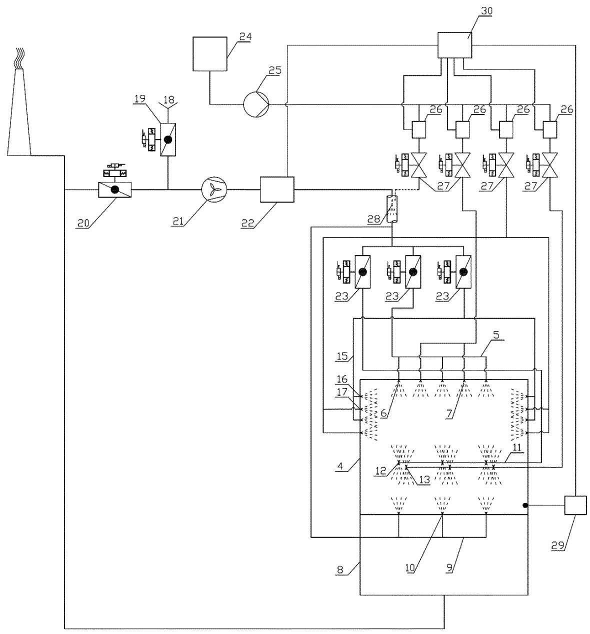

Fig. 1

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Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The object of the invention is a method for the reduction of nitrogen oxides and carbon monoxide in the furnace chambers of water and steam boilers, especially grate boilers and a system for the reduction of nitrogen oxides and carbon monoxide in the furnace chambers of water and steam boilers, especially grate boilers, used to reduce the formation of nitrogen oxides and carbon monoxide and/or their reduction in the furnace chambers of heating boilers and power boilers, especially grate boilers, and a system for the application of this method.

[0002] The methods described in patents PL 196745 B1 and WO 95/15463 require large investment outlays due to the need to install complex cooling systems and, moreover, insertion of a pipe inside the combustion chamber means that the pipe has to be moved out periodically or in emergency situations, which results in the need to install expensive drive systems and requires provision of relatively large space around the combustion chamber; as this is not always possible, it makes it practically impossible to apply these solutions in certain cases.

[0003] The methods described in patent US 20160003473 A1 present solutions which consist in inserting into the combustion chamber one or more lances supplying air with the reagent through one or two side walls of the boiler. In these solutions, the lances are rigidly fixed directly in the boiler shell, which means there is no need to install drive systems to withdraw the lances or provide considerable space around the combustion chamber; however, periodic inspection and cleaning of the lances requires stopping the combustion process inside the boiler. When this method of installation is used, the length and diameter of the lances are also limited due to the stress to which they are subjected inside the boiler and the total weight of equipment.

[0004] The methods described in patents US 2006/0118013 A1 and WO 2013/09566 A2 focus on how to introduce the reagent with secondary air through nozzles placed in one or more walls of the boiler. Such a method of reagent injection with secondary air significantly reduces investment outlays and operating costs of the solution, however, it also limits the selection of the appropriate angle of reagent injection with secondary air and may lead to a situation where these substances are not introduced directly into the very centre of the combustion process, but only affect its part located closer to the boiler walls.

[0005] The method described in patent WO 2004/085922 A2 assumes the reduction of NOx emissions by using a method of primary reduction of toxic compounds by splitting the combustion air stream. In this solution, part of the air is supplied near the fuel feed as primary air and the remaining part of the air necessary for full and complete combustion of the fuel is supplied above the fuel feed point, in the higher parts of the combustion area, by means of nozzles located on the walls of the combustion chamber; the air stream supplied in this area forms a swirl parallel or close to a plane perpendicular to the vertical axis of the combustion chamber.

[0006] The method described in the patent application P.423576 assumes that the process gas, or process gas and reagent, are injected into the furnace chamber in the opposite direction to the main natural direction of the flue gas flow through the chamber, preferably from top to bottom, i.e. in the case of injection from the top, side or front wall of the firebox, in the direction of temperature rise in the furnace chamber, and in the case of process gas injection through lances from the back wall of the firebox, as an additional reinforcement of the swirl, the process gas is supplied horizontally, with a jet deviation of +/-45°, in a plane parallel to the longitudinal symmetry plane of the furnace chamber. The process gas injection points are located on the front, top, side or rear wall of the furnace chamber, while the reagent and process gas injection points are located on the front, side or top wall of the furnace chamber, while the process gas injection points are located at a distance of up to 0.5 depth of the furnace chamber from the pipe axis of the front screen while when process gas is injected from the rear wall of the furnace chamber, the injection points are located at a distance of up to 0.2 depth of the furnace chamber from the pipe axis of the rear screen of the chamber. The above described method of feeding process gas or process gas and reagent causes a flue gas stream of high NO_X concentration at the rear wall of the furnace chamber, on a significant part of the boiler width, and the described method of feeding process gas and reagent through lances mounted on the side walls of the boiler furnace chamber makes it possible for the reagent to enter this stream and reduce NO_X compounds in this area.

[0007] The technical problem to be solved is how to eliminate the abovementioned drawbacks and limitations, while guaranteeing further reduction of NO_X emissions, reduction of CO emissions, minimising or completely eliminating the reagent in flue gases and fly ashes, increasing the efficiency of the system and lowering operating costs.

[0008] The essence of the invention which is a method for the reduction of nitrogen oxides and carbon monoxide in the furnace chambers of water and steam boilers, especially grate boilers **consists in that** process gas, being air, flue gas or combustion air mixture, in its full range, i.e. from 0 to 100% share, or in the next combination process gas and reagent, being a solution of ammonia water, or urea solution, preferably a solution of ammonia water with ammonia with a concentration up to 25%, are injected into the furnace chamber, with the injection from lances installed on the front wall of the furnace chamber taking place on one to three levels in the opposite direction to the main, natural direction of the flue gas flow through the furnace chamber, preferably from top to bottom, with a deviation of +/- 15°, the angle being measured between the centre line of the jet and the front wall of the furnace chamber, in a plane parallel to the longitudinal plane of symmetry of the furnace chamber, i.e. in the direction of the temperature rise in the furnace chamber, and part of the injected stream (up to 20%) fed by the lances installed on the front wall of the furnace chamber is injected perpendicularly to the front wall with a possible deviation of the stream +/- 15°, while the stream injected from the lances installed on the rear wall of the furnace chamber takes place towards the front wall at an angle of 30° to 60°, and this angle is measured between the stream centre line and the rear wall of the firebox, in the plane parallel to the longitudinal symmetry plane of the furnace chamber, while the stream injected from the lance installed on the upper wall of the furnace chamber occurs on one to four levels and its direction is opposite to the main direction of the flow of products/semi-finished products of the combustion process, flowing through the furnace chamber of the device, i.e. from top to bottom, in the direction of the boiler grate, with a deviation of the jet of +/-60°, the angle being measured between the centre line of the jet and the symmetry axis of the injection lance, which is perpendicular to the grate deck, in a plane parallel to the longitudinal symmetry plane of the furnace chamber, and this deviation, as well as the number of injection points, varies according to the boiler load, while the injection from the lances mounted on the side walls of the furnace chamber occurs on one to three levels, and the direction of injection is perpendicular to the side walls, i.e. it is perpendicular to the main direction of flow of products/semi-finished products of the combustion process, flowing through the furnace chamber of the device, with a possibility of deflecting the jet by an angle of +/-20°, which means that it goes inside the down swirl, while process gas is supplied to the furnace chamber at a speed of 30 to 180 m/s, preferably 135 m/s, in the amount of up to 20% of stoichiometric air demand necessary to burn the fuel supplied to the boiler, preferably 15%, with up to 60% of the process gas being injected via lances built into the front screen of the furnace chamber, with 60% of the process gas being injected through lances installed on the rear screen of the furnace chamber, up to 25% of the process gas is injected through lances installed on the upper screen of the furnace chamber and up to 15% of the process gas is injected through lances installed on the side screens of the furnace chamber; moreover, the reagent is delivered to the furnace chamber at a rate of 30 to 180 m/s, preferably 135 m/s, where the process gas injection points are located on the front wall of the furnace chamber, and/or on the upper wall of the furnace chamber and/or on the side walls of the furnace chamber, and/or on the rear wall of the furnace chamber, while the reagent and process gas injection points are located on the front wall of the furnace chamber, and/or on the side walls of the furnace chamber, and/or on the upper wall of the furnace chamber and the number of reagent injection points may be equal to or different from the number of process gas injection points; in the case of injection from the front wall of the furnace chamber, the injection points being up to 0.5 depth of the furnace chamber from the axis of the front screen pipes, preferably 0.1 and at a height from 0.2 to 0.8 of the furnace chamber above the grate deck, preferably 0.5; in the case of injection from the upper wall of the furnace chamber, the injection points are at a distance of 0.05 to 0.3 of the furnace chamber depth from the pipe axis of the rear screen of the furnace chamber, preferably 0.15, and at a height of 0.5 to 1.5 of the height of the festoon from the pipe axis of the upper screen, preferably 0.9 of the festoon height, while when injecting from the side walls of the furnace chamber, the injection points are located at a distance of 0.05 to 0.5 of the furnace chamber depth from the axis of the tubes of the rear screen of the furnace chamber and are located on one to three levels, preferably on three levels, with each level located at equal or different distances from the rear screen of the furnace chambers, preferably, the lowest level in the furnace chamber being located farthest from the screen of the rear furnace chamber and the lances are located at a height of 0.1 to 0.7 of the furnace chamber height above the grate deck, and when injected from the rear wall of the furnace chamber, the injection points are located at the bottom edge of the boiler festoon, i.e. at the height of the end of the sheet piling wall of the rear screen of the furnace chamber with a possible shift in both directions up to 0.6 of the festoon height, preferably, at the height of the bottom edge of the festoon, in one of the combinations in the upper part of the furnace chamber there is a set of temperature sensors, depending on the configuration of the system, which depends on the range of changes in boiler output. The amount of process gas or process gas and reagent injected into the furnace chamber can be changed within a full range of regulation, i.e. from 0 to 100%, for particular injection point groups or injection points, by the control unit based on the predefined control diagram i.e. depending on the boiler load as well as on the measured values: temperature and the share of O_2, CO or NO_X in the flue gas, such parameters being monitored by measuring devices mounted inside the furnace chamber in the form of temperature sensors and/or devices mounted outside the furnace chamber being the flue gas analyser, and the regulation is carried out by means of actuators individually for each injection point or group of injection points mounted on a given wall of the furnace chamber, on a given level or with a specific injection direction.

[0009] This method is realized in a system according to the invention, for the reduction of nitrogen oxides and carbon monoxide in furnace chambers of water boilers and steam boilers, especially grate boilers, containing a process gas feeder with a flow regulator, process gas lances, a device measuring the concentration of NOx, CO or NOx, CO and O_2 in flue gases and a controller, the essence of which consists in that the process gas feeder comprising an intake, which through an air duct on which the control and cut-off damper is mounted, is connected to the flue gas duct, through which the flue gas is taken from the section of the flue gas duct connecting the dedusting or dedusting and desulfurizing system with the chimney, and on this duct there is also a control and cut-off throttle, by means of which the ratio of air to flue gases in the process gas is regulated, then through the common duct the process gas is sucked in by the process gas fan and pumped from the process gas feeder to the process gas delivery duct, on the process gas duct a group of devices are mounted which are used to measure the stream, and further on the installation branches out into a number of systems, up to five systems and preferably four, which supply process gas to individual groups of ejection lances mounted on the walls of the furnace chamber, on each of the zone systems there is a control and cut-off throttle for process gas and a pressure sensor, and these elements are used to control the process gas stream supplied to a given zone, and directly before the system is connected to the injection lance, there are built-in elements that cut off individual lances; there is also a version in which a fan with a frequency converter is used to control the process gas flow supplied from one to two lines, in the case of zones requiring the highest pressures, while the reagent is supplied to the system through a reagent feeder consisting of the following components connected with each other in a similar way: a tank and pumps equipped with shut-off and filter components, pumps equipped with frequency converters responsible for maintaining appropriate pressure in the reagent system on the section between the pumps and the control and cut-off elements, flow measurement devices installed behind the pumps and before the control and cut-off components of the system, and such components, through the pipe system and through elements cutting off individual injection points located on the furnace chamber, deliver the reagent to the furnace chamber; in a different configuration the reagent is injected at one point into the main process gas collector or at several points into individual process gas collectors supplying individual groups of injection lances located on the furnace chamber walls; or the reagent is injected into the collectors either in liquid form or, after evaporation in the evaporator, in gaseous form, both the amount of process gas and the reagent as well as the injection locations and directions are adjusted by the control unit on the basis of the current load of the device and on the basis of current readings from control and measuring devices such as temperature sensors and/or from the flue gas analyser; process gas and reagent injection lances are placed on at least one of the walls of the furnace chamber on at least one level, while the device measuring the NOx, CO and O_2 concentrations in the flue gas is installed in or behind the convection part of the boiler; from this device the signal is sent to the control device, which in turn controls the flow rate of process gas and reagent through actuators and measuring devices installed on the systems.

In an alternative version, a liquid or gaseous reagent is injected centrally through at least one lance into the process gas collector.

In another version, the reagent is injected into the furnace chamber together with the process gas through nozzles installed inside the process gas injection lances, where the number of reagent nozzles is equal or lower than the number of process gas lances.

There is also a version in which, together with the process gas, the reagent is injected into the furnace chamber by means of nozzles installed between the process gas injection lances at the level of the process gas lances, and the number of reagent lances is equal to or lower than the number of process gas lances.

In yet another version, the process gas is supplied to the lances directly from the fan and the reagent is supplied directly from the zonal control and cut-off components.

[0010] Due to this solution, in the presented invention according to the method, the dynamic effect of the process gas stream was used to intensify the mixing process in the furnace chamber by inducing strong internal flue gas recirculation inside the furnace chamber and a strong swirl whose direction is opposite to the main, natural flue gas flow direction and the swirl plane is parallel to the longitudinal symmetry plane of the furnace chamber. This solution results in the equalisation of the temperature profile in the furnace chamber, which equalizes the thermal load of the chamber, which in turn leads directly to an increase in the efficiency and service life of the equipment; the solution according to the method allows for precise control of the temperature in the furnace chamber in the area where nitrogen oxides are reduced and CO is burned, reducing the concentration of the reagent in the furnace chamber, which minimises the risk of corrosion of the equipment components; moreover, the invention according to one of the embodiments, increases the capacity of the system by placing the lances on several levels of the furnace chamber, especially in the case of a considerable variability of the boiler load and this is usually used in units with higher power output. The invention according to the method also reduces reagent consumption in relation to known methods and thus allows to minimize the content of unreacted reagent in fly ashes and flue gases, which plays a very important role in terms of system operating costs, environmental protection and ash management. The opposite direction of reagent injection in relation to the main, natural direction of flue gas flow and to the inside of the generated swirls, as well as the described points and directions of injection, have a very important advantage in relation to the traditional directions and places of reagent injection cited in the state of the art investigation, because in the described method according to the invention, there is no such phenomenon (or if it occurs it is limited to a minimum) as entrainment of unreacted reagent particles, directly after it has been injected into the furnace chamber by the flue gases into the convection part of the boiler, i.e. the place where there are no conditions (no appropriate temperature window range), for the reduction reaction to occur, and further on into the flue gas treatment and discharge systems; another advantage of the method according to the invention resulting from the opposite direction of the reagent feeding in relation to the flue gas flow direction and the inner direction of the generated swirl is, in comparison with the known methods, much longer time from the injection of the reagent into the furnace chamber into the area of relatively low temperature until the occurrence of a reduction reaction, in which the reagent mixes with the process gas and combustion products moving in the direction of the temperature rise, i.e. towards the combustion area, where the reduction reaction takes place in the temperature range from 850°C to 1050°C and in the presence of nitrogen compounds; further on, the unreacted particles of the reagent enter the temperature area above 1050°C where they bind with oxygen and form NO_X-type compounds, which then, together with the products of combustion, head up the furnace chamber in accordance with the main natural draught of the combustion chamber where they encounter the unreacted reagent and the temperature conditions required for the occurrence of the NOX reduction reaction; part of the still unreacted reagent and unreacted nitrogen compounds (NOX) are returned to an area convenient for the NOX reduction reaction, through strong swirls of recirculating flue gas produced by the process gas stream. This natural and spontaneous course of the process contributes to the efficiency of the reduction process and to a large extent protects the system against the ingress of unreacted reagent into the ash, dust or flue gas treatment and discharge systems; another advantage of the method according to the invention is that the process gas is injected into the furnace chamber in the opposite direction to the natural direction of the flue gas movement in the furnace chamber and at a high rate turns back towards the grate i.e. into the high temperature area, particles of unburned coal, which in the hitherto known solutions are entrained from the layer of coal moving on the grate by the blast air supplied from the grate and, as coal, together with fly ashes enter the dust extraction systems significantly reducing their efficiency. The presented method according to the invention, significantly reduces the content of the carbon element in fly ash, which directly contributes to the increase in the efficiency of the system and also reduces the amount of fly ash carried by the flue gases leaving the boiler and entering the dedusting systems, which extends the service life of the devices and in newly built units enables the use of smaller first-stage dedusting systems reducing the equipment cost. This effect is particularly noticeable when burning poorer quality coal containing a lot of coal fines.

[0011] The presented method of feeding the process gas or process gas and reagent produces a strong, main, reverse internal recirculation swirl and, depending on the boiler capacity, one to two additional swirls, one called the upper swirl, which is formed in the area bounded by the front screen, the upper and the stream of process gas injected from the lances mounted on the rear screen of the furnace chamber, this swirl being particularly noticeable at medium and high boiler loads, and a second one, called the down swirl, which is formed in the area bounded by the rear screen, the grate deck and the flue gas stream moving from the front zones of the grate towards the rear screen and further on towards the festoon, this swirl being particularly noticeable at low boiler loads; the main swirl and the upper swirl generated at medium and high boiler loads suck in flue gases from the main flue gas stream, from the area just before the furnace chamber is connected to the convection line, and thus create optimal conditions for nitrogen oxide reduction and carbon monoxide afterburning, with minimal oxygen content in flue gas and minimum amount of reagent entering the chimney; this limiting effect is due to the fact that the opposite direction of reagent injection consistent with the direction of temperature increase in the furnace chamber and strong internal recirculation ensure sufficient time to mix the reagent with process gas and flue gas, resulting in a homogeneous mixture, thus reducing the time needed for the NOX reduction reaction, which occurs after the mixture enters the area with a temperature between 850°C and 1050°C; subsequently, the excess unreacted reagent enters the area where the temperature is above 1050°C where it combines with oxygen to form NOX compounds, which are then transported with the main flue gas stream to a lower-temperature area of the furnace chamber, where the reagent is again encountered and reduction takes place; part of the flue gas just before the connection of the furnace chamber with the boiler's convection line is returned again as a result of strong recirculation swirls and reaches subsequent zones; a similar mechanism is produced by a down swirl, which is visible at low boiler loads, except that the flue gases from the main flue gas stream are sucked in from the lower parts of the boiler and not, as before, from the festoon area and are returned towards the grate deck, which in the case of low boiler loads ensures that a suitable temperature range for NOx reduction reaction is maintained; this self-looping process ensures low NO_X emissions from the system and low reagent consumption, low CO emissions with low oxygen content in the flue gas, low content of carbon and unreacted reagent in the fly ash, as well as reduced amount of fly ash carried by the flue gas leaving the boiler.

[0012] The invention in an exemplary but not restrictive embodiment is shown in the following drawings:

Fig. 1 - Block diagram of the system to execute the method,

Fig. 2 - A diagram of the boiler showing the location of the lances injecting process gas and reagent into the furnace chamber with marked directions of flue gas, process gas and reagent flows and the resulting reverse swirl and internal recirculation of flue gas.

[0013] Figure 1 shows the block diagram of the system for the realization of the method where: 4 - is the furnace chamber, 5 - is the front process gas/reagent collector, 6 - is the front process gas injection lance, 7 - is the front reagent injection lance/nozzle, 8 - is the convection part of the boiler, 9 - is the rear process gas collector, 10 - is the rear reagent injection lance, 11 - is the upper process gas/reagent collector, 12 - is the upper process gas injection lance, 13 - is the upper reagent injection lance, 15 - is the side process gas/reagent collector, 16 - is the side process gas injection lance, 17 - is the side reagent injection lance, 18 - is the process gas intake, 19 - is the control and shut-off component of the process gas feeder - air system, 20 - is the control and shut-off component of the process gas feeder - flue gas system, 21 - is the process gas fan, 22 - is the measuring system installed on the process gas collector, 23 - is the control and shut-off component of the process gas system, 24 - is the reagent tank, 25 - is the reagent pump, 26 - is the measuring system built on the reagent installation, 27 - is the control and cut-off components mounted on the reagent installation, 28 - is the lance for the central injection of the reagent into the process gas, 29 - is the device measuring the flue gas composition, 30 - is the controller.

[0014] Figure 2 shows in a schematic and illustrative manner the place of installation of process gas and reagent injection lances, as well as the flow lines and swirl directions which occur during combustion in the furnace chamber of the equipment, preferably a grate boiler, where: 1 - is the sub-grate box of air, 2 - is the layer of fuel moving on the grate, 3 - is the grate, 4 - is the furnace chamber, 5 - is the front process gas/reagent collector, 6 - is the front process gas injection lance, 7 - is the front reagent injection lance/nozzle, 8 - is the convection part of the boiler, 9 - is the rear process gas collector, 10 - is the rear reagent injection lance, 11 - is the top process gas/reagent collector, 12 - is the top process gas injection lance, 13 - is the top injection lance of the reagent, 14 - is the temperature sensor, 15 - is the side collector of the process gas/reagent, 16 - is the side injection lance of the process gas, 17 - is the side injection lance of the reagent, A - is the blast air stream (primary), PG - is process gas stream, PG+R - is process gas and reagent stream, FG - is flue gas stream, iFGR - is internal flue gas recirculation, MS - is main swirl, DS - is down swirl and US - is upper swirl.

[0015] The example embodiment according to the method will be illustrated by Fig. 2 in which A is the primary air pumped by the blast air fan to the control valves and then to the sub-grate boxes 1, whose task is to dose the oxidant in a controlled way to fuel 2 moving on the grate 3. On and directly above grate 3, fuel is burned and the amount of oxidant supplied in the form of primary air A ranges from 0.7 to 1.3 of the amount of stoichiometric air needed for full and complete combustion of fuel 2, preferably less than 1.0, moving on grate 3 as defined by the standards for this type of equipment. The products and semi-finished products of FG combustion, move towards the top of furnace chamber 4, part of which goes near the rear wall of furnace chamber 4, which is a phenomenon normally found in furnace chambers of boilers of this kind. At a distance of 0.05 of the depth of furnace chamber 4, at the height of 0.5 of the height of the boiler's furnace chamber, on the front wall of furnace chamber 4, process gas (PG) or process gas and reagent (PG+R) are injected through collector 5 mounted outside the chamber, up to 60% of the process gas supplied to the system, through a series of lances 6 and 7 made and installed in such a way that the direction of injection of process gas (PG) or process gas with reagent (PG+R) is opposite to the main direction of flow through the furnace chamber 4 with a jet deviation of +/-15° in the plane parallel to the longitudinal symmetry plane of the furnace chamber, whereby part of the process gas (PG) or process gas with reagent (PG+R) accounting for up to 20% of the total amount of the process gas or process gas and reagent fed through lances 6 and 7 installed on the front wall of furnace chamber 4, is injected in a direction perpendicular to the front wall with a possible deviation of the jet of +/- 15°, i.e. towards the centre of the emerging swirl, while another portion of process gas (PG) accounting for up to 60% of the process gas supplied to the system through collector 9 built in the convection part of boiler 8 and through lances 10 mounted on the rear wall of the furnace chamber 4, at the level of the lower edge of the boiler festoon is injected in the direction of grate 3 at an angle of 45°, and this angle is measured between the centre line of the jet and the back wall of the furnace chamber and another portion of process gas (PG) or process gas and reagent (PG+R) accounting for up to 25% of the process gas supplied to the system, via collector 11 mounted outside the boiler furnace chamber and through lances 12 and 13 mounted on the upper wall of the boiler furnace chamber 4 is injected in the opposite direction to the main direction of the FG flow through furnace chamber 4, whereby injection from each of lances 12 and/or 13 is made from at least one point, with a jet deviation of up to +/- 60° in the plane parallel to the longitudinal symmetry plane of the furnace chamber; the remaining process gas (PG) or process gas and reagent (PG+R) is injected through collector 15 mounted outside the boiler, through lances 16 and 17 mounted on the side walls of furnace chamber 4 of the boiler, in a direction perpendicular to these walls with a jet deviation of +/-20° at least on one level. The injection rate of process gas (PG) or reagent (R) is from 30 to 180 m/s, preferably 135 m/s, and the process gas stream accounts for up to 20% of the air stream necessary for full and complete combustion of the fuel as defined by the standards for this type of equipment; due to high speed, significant mass of the process gas stream and the way it is fed into the furnace chamber, a strong internal recirculation of iFGR flue gas inside furnace chamber 4 and a strong main swirl (MS) are produced, and depending on the boiler capacity, one or two additional swirls, one called upper swirl (US) and the other called down swirl (DS); the swirls rotate in a plane parallel to the longitudinal symmetry plane of the furnace chamber. Lance 6 and 7 are shaped similarly to letter "L" and are introduced through deflections made in the front wall of furnace chamber 4. Thanks to the way in which lance 6 and 7 are fixed, it possible to change their position in the plane parallel to the longitudinal plane of symmetry of the boiler by +/- 15°. The back lances 10 are mounted directly in the boiler festoon or are introduced through the deflections made in the back wall of furnace chamber 4. The top lances 12 and 13 are mounted on the ceiling of furnace chamber 4 and are introduced through deflections made in this wall and each of the lances has at least one injection point. In accordance with the patented method according to the invention, such a method of feeding process gas PG and reagent R is conducive to creating favourable conditions for conducting the process of nitrogen oxide reduction with very high efficiency due to the fact that the reagent after injection into furnace chamber 4 mixes with the injected process gas and combustion products moving in the direction of the temperature rise, i.e. towards the combustion area, where the reduction reaction takes place in a temperature range from 850°C to 1050°C and in the presence of nitrogen oxides; the excess unreacted reagent R is transported to an area of increasingly higher temperature where the unreacted reagent reacts with oxygen and forms nitrogen oxides, which then, together with the products of combustion, head up the furnace chamber in a direction consistent with the main natural draught in the furnace chamber, where they encounter an unreacted reagent and suitable temperature conditions for the occurrence of the reduction reaction; part of the still unreacted reagent and unreduced nitrogen compounds (NO_X) just before leaving the furnace chamber is returned to the area with suitable conditions for the reduction reaction by a strong stream of recirculating exhaust gas produced by the process gas stream. The feeding of process gas and reagent in a manner according to the invention creates a strong main reverse swirl parallel to the longitudinal plane of symmetry of the furnace chamber and, depending on the boiler output, additionally an upward or downward swirl, which rotate in the same plane as the main swirl but in opposite directions; as a result, the system is, in a broad spectrum of operation, a self-regulating system, thus protecting itself against the ingress of unreacted reagent into the exhaust gases and ashes; moreover, the system according to the invention is hardly sensitive to fluctuations in the amount of nitrogen oxides produced in the process of burning fuel on the grate. In addition, due to the fact that the process gas is injected into the furnace chamber in the opposite direction to the natural direction of the flue gas movement in the furnace chamber and at high rate, it returns towards the grate, i.e. into the high-temperature area, particles of unburned coal, which in the hitherto known solutions, are entrained from the layer of coal moving on the grate by the blast air supplied from the grate and, as coal, enter together with fly ashes into the dust extraction systems, significantly reducing the overall equipment efficiency. The presented method, according to the invention, significantly reduces carbon content in fly ashes, which directly contributes to the increase in boiler efficiency, as well as reduction in the amount of fly ashes captured by flue gases leaving the boiler and the content of unreacted reagent in such ashes entering the dedusting systems, resulting in the extension of the service life of these units due to the reduction of erosion and corrosion of the equipment and in newly built units allows for the use of smaller first-stage dedusting systems, reducing the related costs.

[0016] The invention may be used in all applications where emphasis is placed on high quality of the combustion process, low emissions, especially of nitrogen oxides and carbon monoxide, investment savings, energy savings, and reagent savings, i.e. operating costs. The method presented in the description is intended for use in heating boilers and power boilers, especially grate-type boilers.

[0017] The following benefits have been achieved thanks to the invention:

- minimisation of investment costs,
- minimisation of operating costs,
- substantial simplification of the installation,
- minimisation of the space needed to install the system,
- reliability of operation,
- reduction of NOX emissions,
- reduction of carbon monoxide (CO) emissions,
- reduction of the carbon content in fly ashes,
- reduction of fly ash content in flue gases,
- increase in the efficiency of the equipment, compared to the known methods, by reducing the O2 and CO content in flue gas and carbon content in fly ashes,
- increase in the efficiency of the system by replacing the injection of water into the furnace chamber to distribute the reagent across the chamber or to atomise the reagent , by using process gas or compressed air, respectively,
- reduction of the unreacted reagent content in flue gas and ashes compared to known methods,
- increase the service life of the equipment by reducing the concentration of the reagent in the furnace chamber, especially at the walls of the furnace chamber, and by equalizing the temperature profile across the furnace chamber,
- increase in the thermal efficiency of the furnace chamber by increasing the average heat flow returned to the walls of the furnace chamber.

Claims

1. The method for the reduction of nitrogen oxides and carbon monoxide in the furnace chambers of water and steam boilers, especially grate boilers, **characterized in that** the process gas, being air, flue gas or combustion air mixture, in its full range, i.e. from 0 to 100% share, or in the next combination process gas and reagent, being a solution of ammonia water,

or urea solution, preferably a solution of ammonia water with ammonia with a concentration up to 25%, are injected into the furnace chamber, with the injection from lances installed on the front wall of the furnace chamber taking place on one to three levels in the opposite direction to the main, natural direction of the flue gas flow through the furnace chamber, preferably from top to bottom, with a deviation of +/- 15°, the angle being measured between the centre line of the jet and the front wall of the furnace chamber, in a plane parallel to the longitudinal plane of symmetry of the furnace chamber, i.e. in the direction of the temperature rise in the furnace chamber, and part of the injected stream (up to 20%) fed by the lances installed on the front wall of the furnace chamber is injected perpendicularly to the front wall with a possible deviation of the stream +/- 15°, while the stream injected from the lances installed on the rear wall of the furnace chamber takes place towards the front wall at an angle of 30° to 60°, and this angle is measured between the stream centre line and the rear wall of the firebox, in the plane parallel to the longitudinal symmetry plane of the furnace chamber, while the stream injected from the lance installed on the upper wall of the furnace chamber occurs on one to four levels and its direction is opposite to the main direction of the flow of products/semi-finished products of the combustion process, flowing through the furnace chamber of the device, i.e. from top to bottom, in the direction of the boiler grate, with a deviation of the jet of +/-60°, the angle being measured between the centre line of the jet and the symmetry axis of the injection lance, which is perpendicular to the grate deck, in a plane parallel to the longitudinal symmetry plane of the furnace chamber, and this deviation, as well as the number of injection points, varies according to the boiler load, while the injection from the lances mounted on the side walls of the furnace chamber occurs on one to three levels, and the direction of injection is perpendicular to the side walls, i.e. it is perpendicular to the main direction of flow of products/semi-finished products of the combustion process, flowing through the furnace chamber of the device, with a possibility of deflecting the jet by an angle of +/-20°, which means that it goes inside the down swirl, while process gas is supplied to the furnace chamber at a speed of 30 to 180 m/s, preferably 135 m/s, in the amount of up to 20% of stoichiometric air demand necessary to burn the fuel supplied to the boiler, preferably 15%, with up to 60% of the process gas being injected via lances built into the front screen of the furnace chamber, with 60% of the process gas being injected through lances installed on the rear screen of the furnace chamber, up to 25% of the process gas is injected through lances installed on the upper screen of the furnace chamber and up to 15% of the process gas is injected through lances installed on the side screens of the furnace chamber; moreover, the reagent is delivered to the furnace chamber at a rate of 30 to 180 m/s, preferably 135 m/s, where the process gas injection points are located on the front wall of the furnace chamber, and/or on the upper wall of the furnace chamber and/or on the side walls of the furnace chamber, and/or on the rear wall of the furnace chamber, while the reagent and process gas injection points are located on the front wall of the furnace chamber, and/or on the side walls of the furnace chamber, and/or on the upper wall of the furnace chamber and the number of reagent injection points may be equal to or different from the number of process gas injection points; in the case of injection from the front wall of the furnace chamber, the injection points being up to 0.5 depth of the furnace chamber from the axis of the front screen pipes, preferably 0.1 and at a height from 0.2 to 0.8 of the furnace chamber above the grate deck, preferably 0.5; in the case of injection from the upper wall of the furnace chamber, the injection points are at a distance of 0.05 to 0.3 of the furnace chamber depth from the pipe axis of the rear screen of the furnace chamber, preferably 0.15, and at a height of 0.5 to 1.5 of the height of the festoon from the pipe axis of the upper screen, preferably 0.9 of the festoon height, while when injecting from the side walls of the furnace chamber, the injection points are located at a distance of 0.05 to 0.5 of the furnace chamber depth from the axis of the tubes of the rear screen of the furnace chamber and are located on one to three levels, preferably on three levels, with each level located at equal or different distances from the rear screen of the furnace chambers, preferably, the lowest level in the furnace chamber being located farthest from the screen of the rear furnace chamber and the lances are located at a height of 0.1 to 0.7 of the furnace chamber height above the grate deck, and when injected from the rear wall of the furnace chamber, the injection points are located at the bottom edge of the boiler festoon, i.e. at the height of the end of the sheet piling wall of the rear screen of the furnace chamber with a possible shift in both directions up to 0.6 of the festoon height, preferably, at the height of the bottom edge of the festoon.

2. The method according to claim 1 **characterized in that** in the upper part of the furnace chamber there is a set of temperature sensors, depending on the configuration of the system, which depends on the range of changes in boiler output. The amount of process gas or process gas and reagent injected into the furnace chamber can be changed within a full range of regulation, i.e. from 0 to 100%, for particular injection point groups or injection points, by the control unit based on the predefined control diagram i.e. depending on the boiler load as well as on the measured values: temperature and the share of O_2, CO

or NO_X in the flue gas, such parameters being monitored by measuring devices mounted inside the furnace chamber in the form of temperature sensors and/or devices mounted outside the furnace chamber being the flue gas analyser, and the regulation is carried out by means of actuators individually for each injection point or group of injection points mounted on a given wall of the furnace chamber, on a given level or with a specific injection direction.

3. A system for the reduction of nitrogen oxides and carbon monoxide in furnace chambers of water boilers and steam boilers, especially grate boilers, containing a process gas feeder with a flow regulator, process gas lances, a device measuring the concentration of NOx, CO or NOx, CO and O_2 in flue gases and a controller, **characterized in that** the process gas feeder comprising an intake (18), which through an air duct on which the control and cut-off damper (19) is mounted, is connected to the flue gas duct, through which the flue gas is taken from the section of the flue gas duct connecting the dedusting or dedusting and desulfurizing system with the chimney, and on this duct there is also a control and cut-off damper (20) and by means of dampers (19) and (20) the ratio of air to flue gases in the process gas is regulated; then through the common duct the process gas is sucked in by the process gas fan (21) and pumped from the process gas feeder to the process gas delivery duct, on the process gas duct a group of measuring devices (22) used to measure the flow are mounted, and further on the installation branches out into a number of systems, up to five systems and preferably four (5), (9), (11) and (15), which supply process gas to individual groups of ejection lances (6), (10), (12) and (16) mounted on the walls of furnace chamber (4), on each of the zone systems there is a control and cut-off damper (23) for process gas and a pressure sensor, and these elements are used to control the process gas stream supplied to a given zone, and directly before the system is connected to the injection lance, there are built-in elements that cut off individual lances.

4. A system according to claim 3 **characterized in that** a fan (21) with a frequency converter is used to control the process gas flow supplied from one to two lines, in the case of zones requiring the highest pressures, while the reagent is supplied to the system through a reagent feeder consisting of the following components connected with each other in a similar way: a tank (24) and pumps (25) equipped with shut-off and filter components (27), pumps (25) equipped with frequency converters responsible for maintaining appropriate pressure in the reagent system on the section between the pumps (25) and the control and cut-off elements (27), flow measurement devices (26) installed behind the pumps and before the control and cut-off components (27) of the system, and such components, through the pipe system and through elements cutting off individual injection points (7), (13) and (17) located on the furnace chamber, deliver the reagent to the furnace chamber (4).

5. A system according to claim 3 **characterized in that** the reagent is injected at one point (29) into the main process gas collector or at several points into individual process gas collectors (5), (11), (15) supplying individual groups of injection lances located on furnace chamber (4) walls.

6. A system according to claim 3 **characterized in that** the reagent is injected into the collectors either in liquid form or, after evaporation in the evaporator, in gaseous form, both the amount of process gas and the reagent as well as the injection locations and directions are adjusted by the control unit (28) on the basis of the current load of the device and on the basis of current readings from control and measuring devices such as temperature sensors (14) and/or from the flue gas analyser (27); process gas and reagent injection lances are placed on at least one of the walls of the furnace chamber on at least one level, while the device (27) measuring the NOx, CO and O_2 concentrations in the flue gas is installed in or behind the convection part of the boiler (8); from this device the signal is sent to the control unit (28), which in turn controls the flow rate of process gas and reagent through actuators and measuring devices installed on the systems.

7. A system according to claim 3 **characterized in that** a liquid or gaseous reagent is injected centrally through at least one lance (23) into the process gas collector.

8. A system according to claim 3 **characterized in that** the reagent is injected into furnace chamber (4) together with the process gas through nozzles (7), (13), (17), installed inside the process gas injection lances (6), (12), (16) where the number of reagent nozzles is equal or lower than the number of process gas lances.

9. A system according to claim 3 **characterized in that** together with the process gas, the reagent is injected into furnace chamber (4) by means of nozzles (7), (13), (17) installed between the process gas injection lances (6), (12), (16) at the level of the process gas lances, and the number of reagent lances is equal to or lower than the number of process gas lances.

10. A system according to claim 3 **characterized in that** the process gas is supplied to lances (6), (12), (16) directly from the fan (21) while the reagent is supplied directly to lances (7), (13), (17) from the zonal control and cut-off components (27).

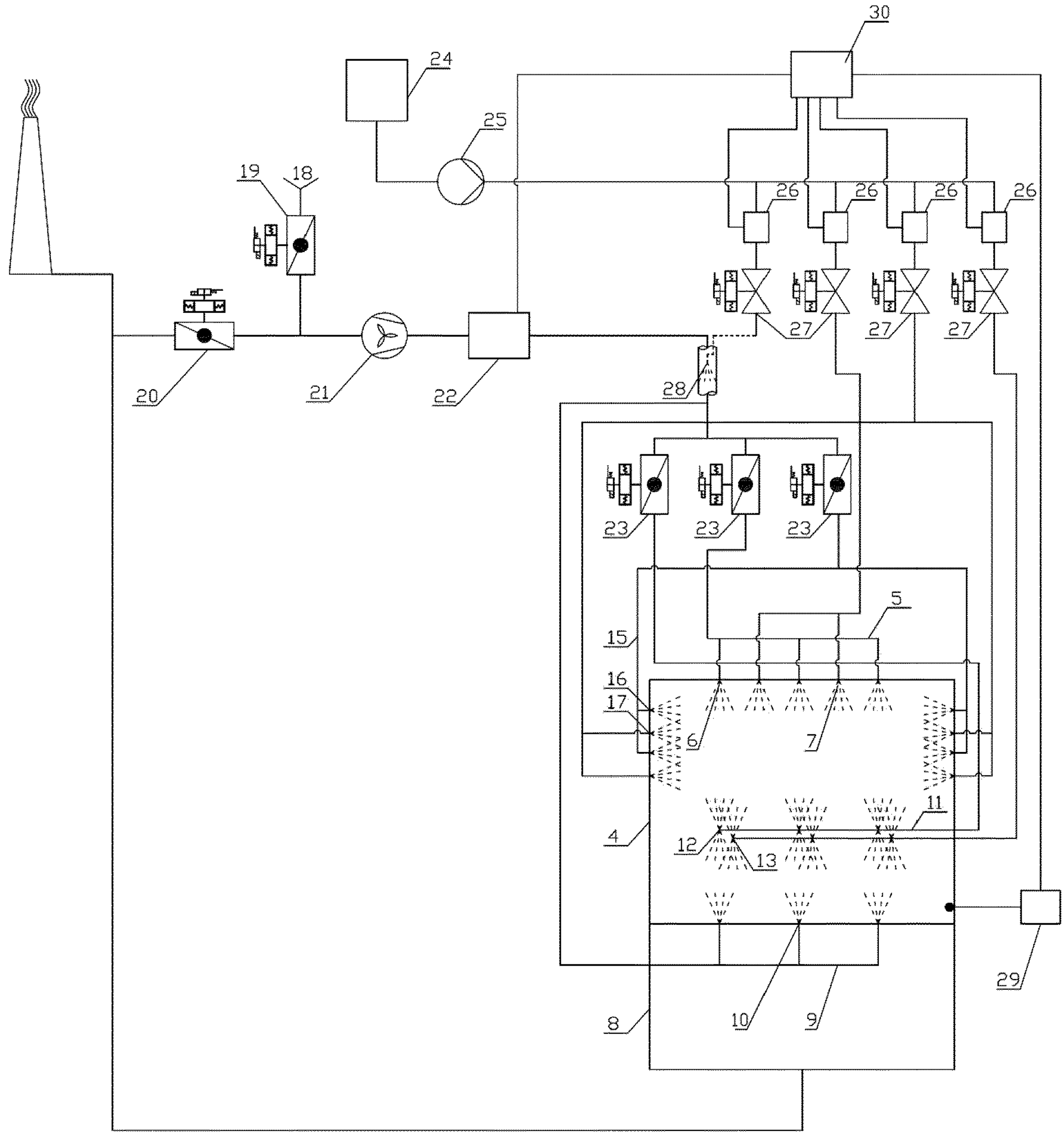
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Fig. 1

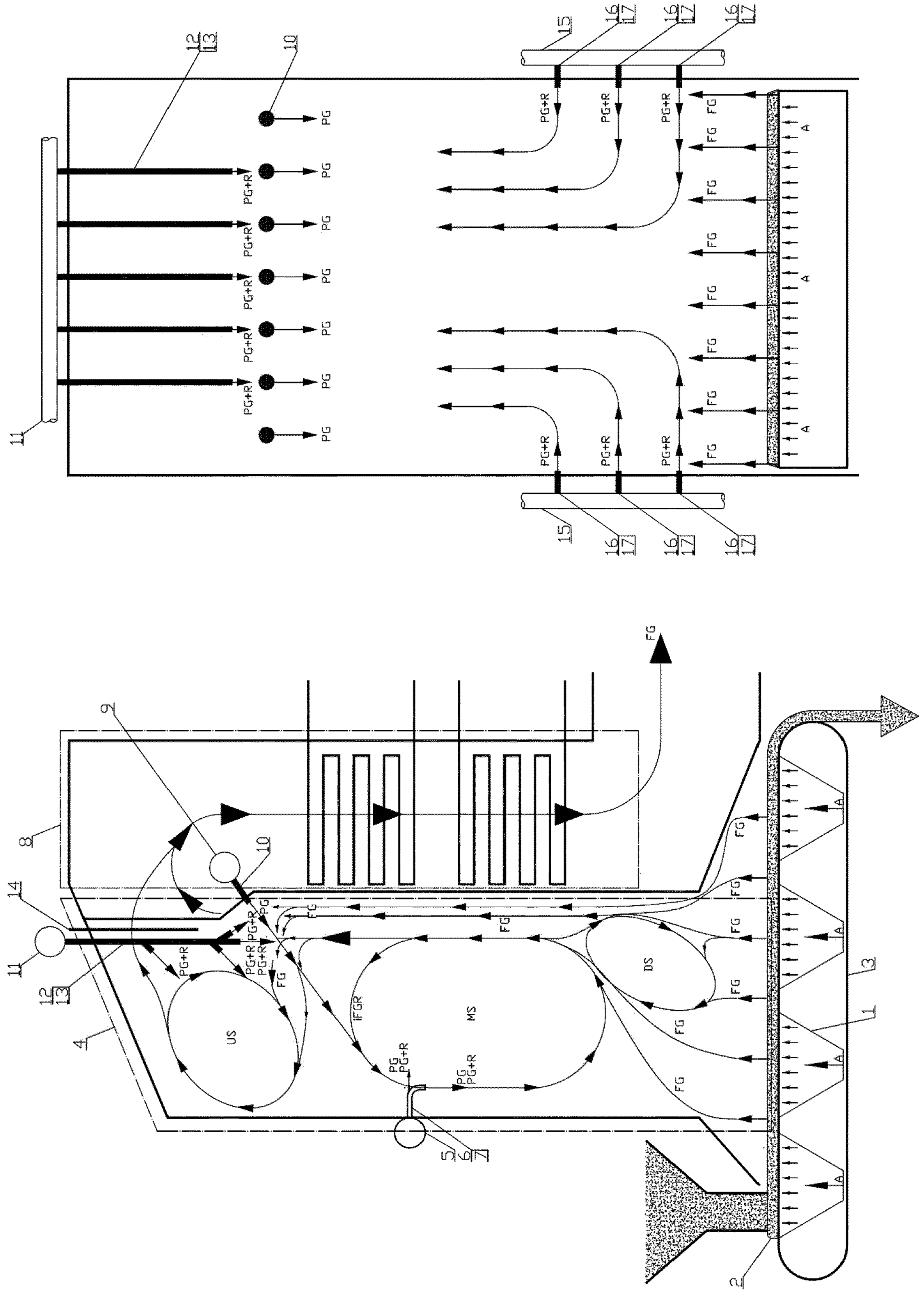

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 02 0236

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Place of search	Date of completion of the search	Examiner
Munich	24 September 2020	Theis, Gilbert

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