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(54) METHOD FOR REDUCING NITROGEN OXIDE(S) AND CARBON MONOXIDE FROM FLUE GASES AND FLUE GAS COMPOSITION

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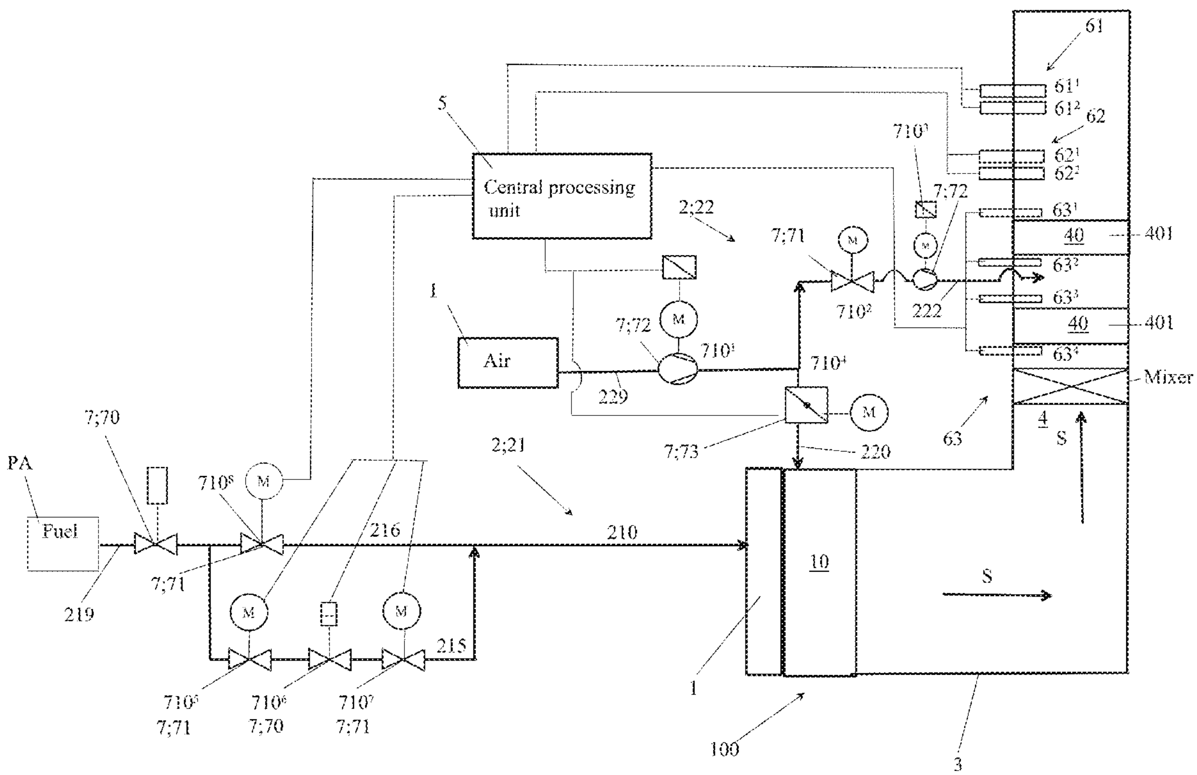
(57) **ABSTRACT**

A method for reducing nitrogen oxide(s) and carbon monoxide from flue gases of an industrial burner adapted to burn gaseous and/or liquid fuel is disclosed. The burner comprises burner automation containing measuring instruments, and a mixing zone accompanied by a combustion chamber. The burner automation is in communication with measurement instruments of flue gas conduit. The combustion chamber or flue gas conduit has two catalytic zones of at least one three-way catalytic converter(s). The catalytic zones are successive in progressing direction of flue gases. An inlet flow (Q_I, Q_{Itot}) of combustion air and an inlet flow (Q_{PA}, Q_{PAtot}) of fuel is delivered into the mixing zone. The flue gases are generated in the combustion chamber by combusting air and fuel delivered into the mixing zone. The amount of residual oxygen is measured in flue gases by a lambda-sensor. The flue gases are directed to at least one three-way catalytic converter(s). The inlet flow (Q_I, Q_{Itot}) of combustion air and the inlet flow (Q_{PA}, Q_{PAtot}) of fuel arriving in the mixing zone is adjusted by the burner automation, so that the mean amount of residual oxygen in moles compared to mean amount of carbon monoxide in moles, is 0.5/1 (mole/mole) and O_2 within the range of 0.01-0.50 vol-% in flue gases prior to or at the first catalytic zone of the at least one three-way converter. Supplementary air is delivered between the first and the second catalytic zones of the three-way converter or between catalytic zones of two successive three-way catalytic converters, so that concentration in the flue gases after said catalytic zones is within range of 0-9 ppm for NOx and within a range of 0-100 ppm.



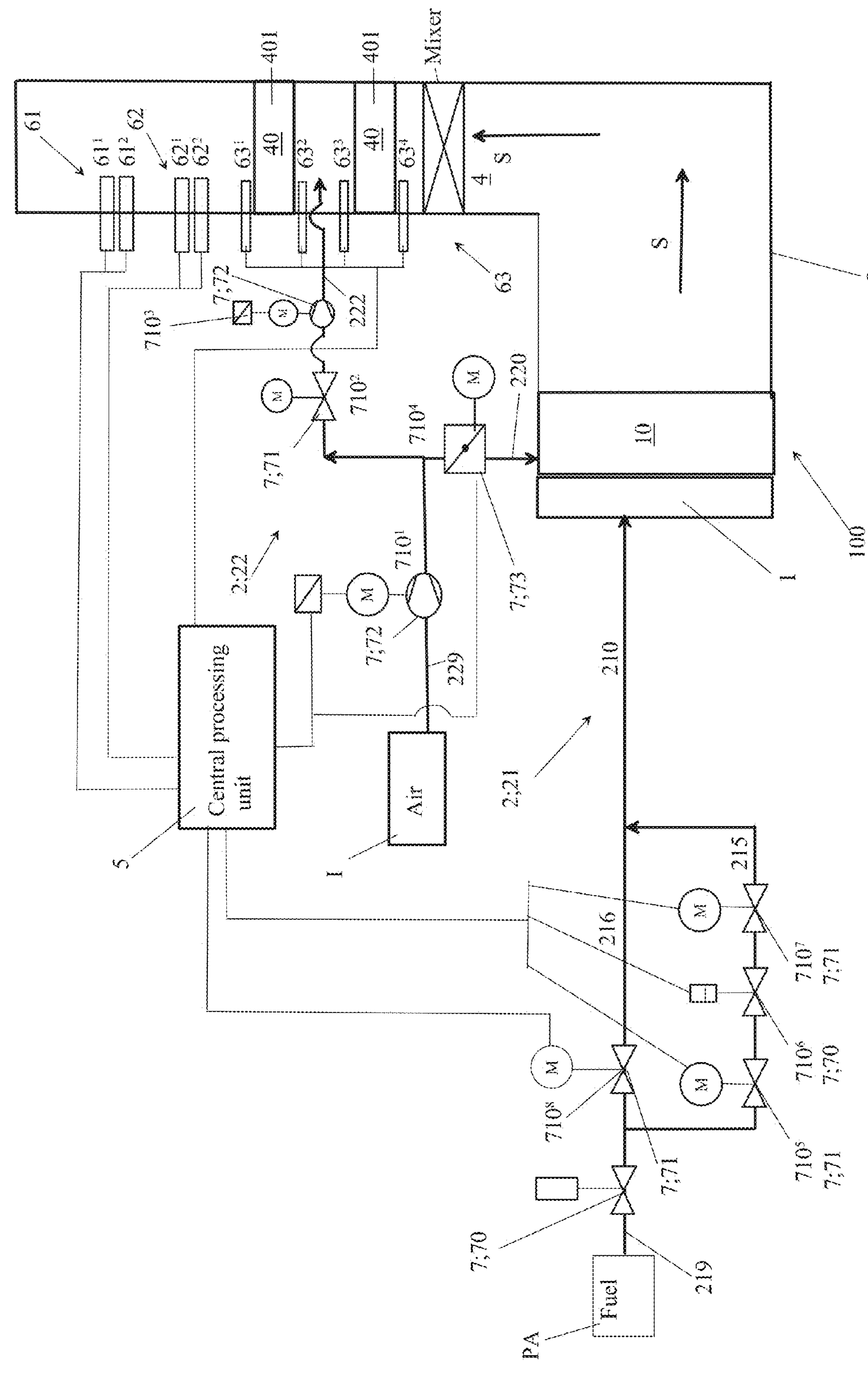
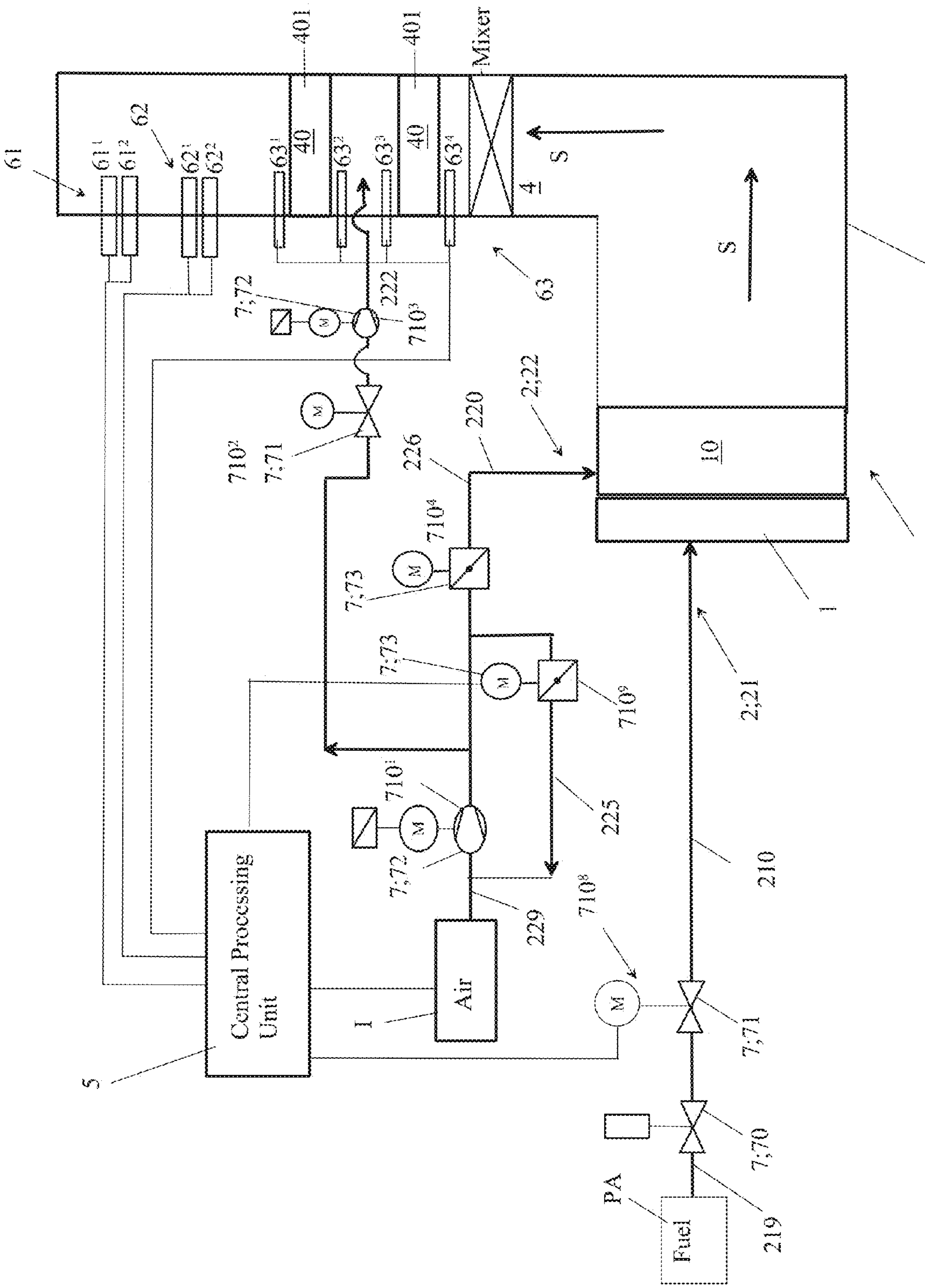
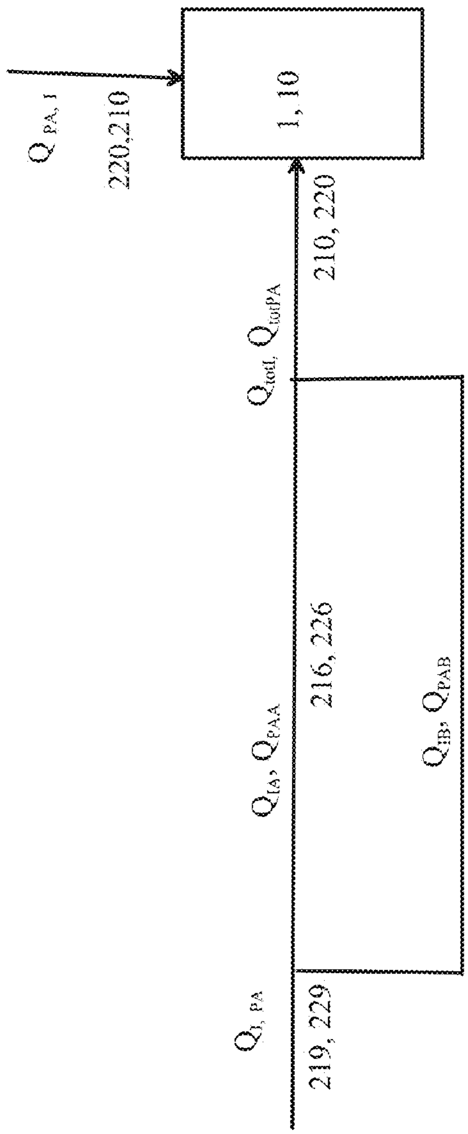

Mixer
Central processing unit
Air
Fuel
401
40
10
S
61
62
63
100
210
220
222
229
215
216
219
2;21
2;22
7;70
7;71
7;72
7;73
PA
M

Fig. 1



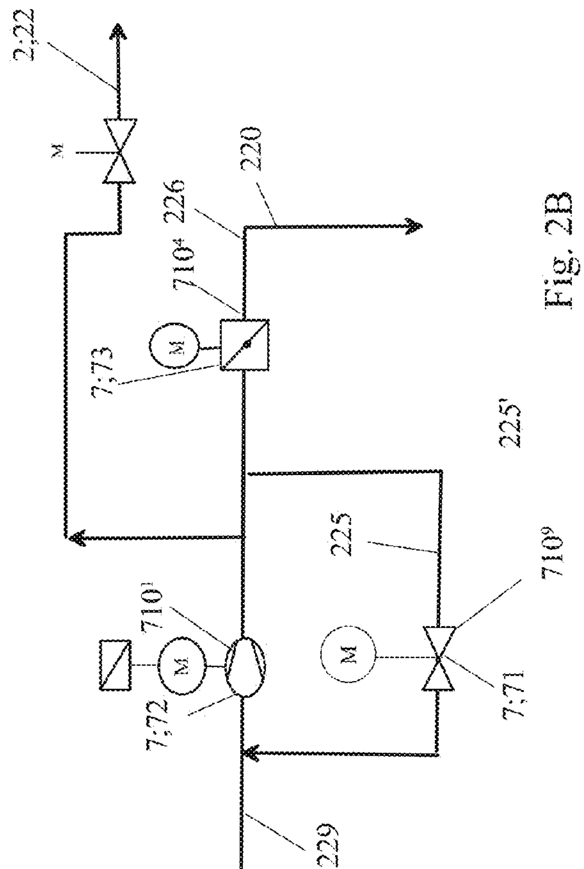
Central Processing Unit
Air
Fuel
Mixer
PA
S
S
61
62
63
3
4
5
I
1
10
40
40
401
401
100
2;21
2;22
210
219
220
222
225
226
229
7;70
7;71
7;71
7;72
7;72
7;73
7;73

Fig. 2A



$Q_{PA,1}$
220,210
1, 10
210, 220
Q_{totl}, Q_{totPA}
Q_{IA}, Q_{PAA}
216, 226
Q_{IB}, Q_{PAB}
215, 225
$Q_{I,PA}$
219, 229

Fig. 3



2;22
M
220
226
710^4
7;73
M
225'
225
710^9
710^1
M
M
7;72
7;71
229

Fig. 2B

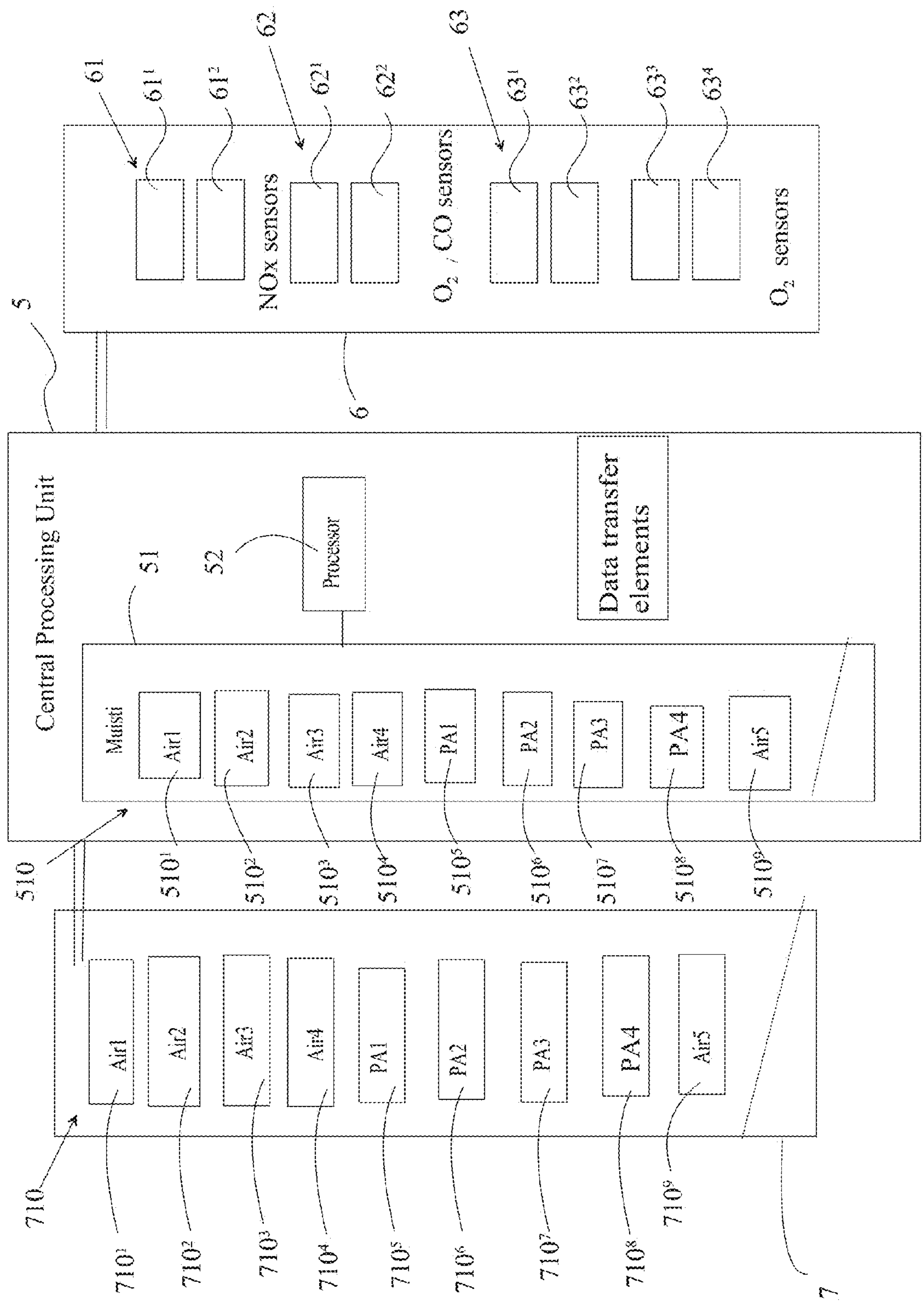

5
6
61
62
63
NOx sensors
O2 / CO sensors
O2 sensors
Central Processing Unit
51
52
Processor
Data transfer elements
Muisti
Air1
Air2
Air3
Air4
PA1
PA2
PA3
PA4
Air5
510
710
7

Fig. 4

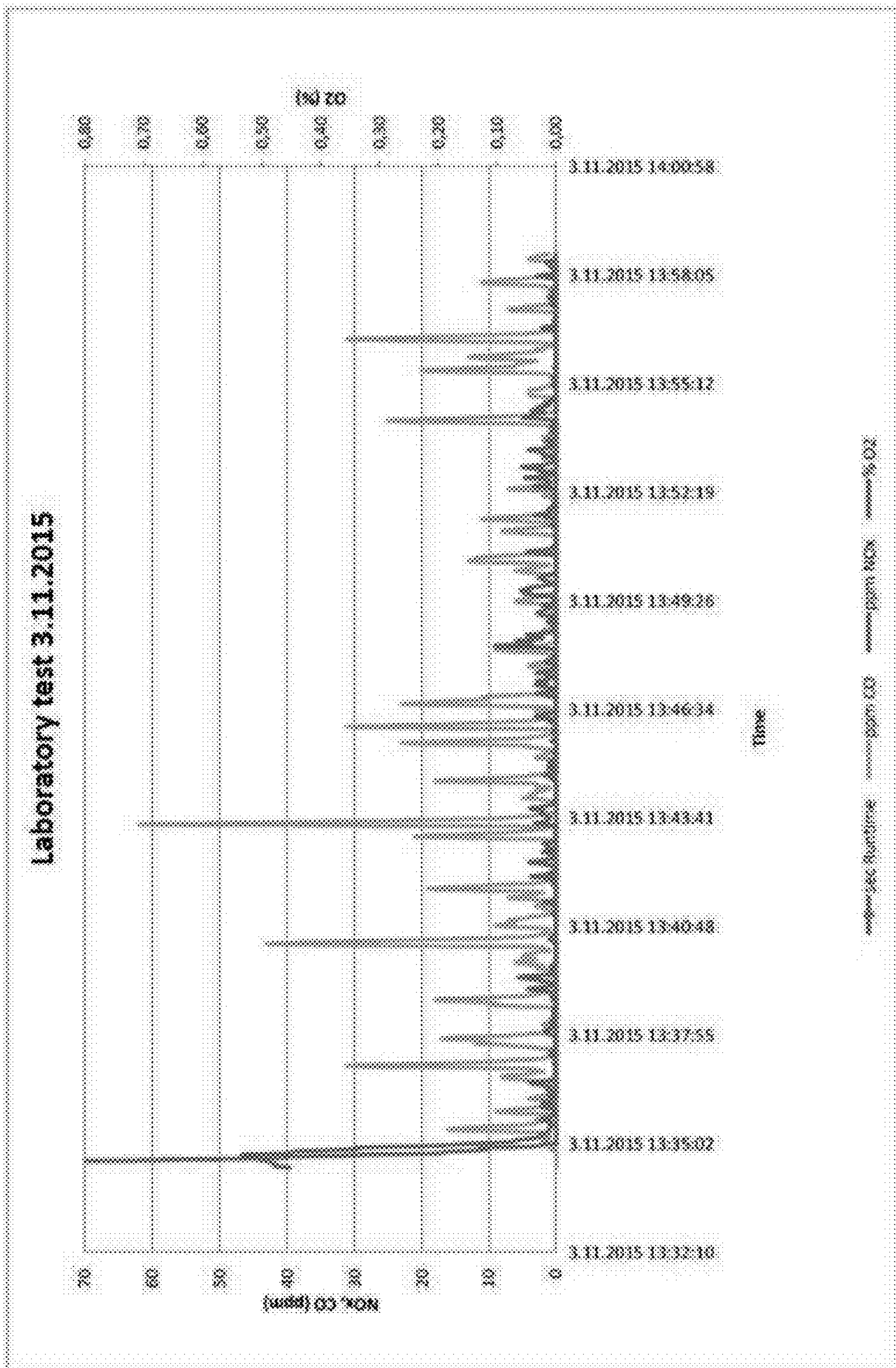

Laboratory test 3.11.2015
NOX, CO (ppm)
O2 (%)
0
10
20
30
40
50
60
70
0,00
0,10
0,20
0,30
0,40
0,50
0,60
0,70
0,80
3.11.2015 13:32:10
3.11.2015 13:35:02
3.11.2015 13:37:55
3.11.2015 13:40:48
3.11.2015 13:43:41
3.11.2015 13:46:34
3.11.2015 13:49:26
3.11.2015 13:52:19
3.11.2015 13:55:12
3.11.2015 13:58:05
3.11.2015 14:00:58
Time
ppm CO
ppm NOX
% O2

Fig. 5

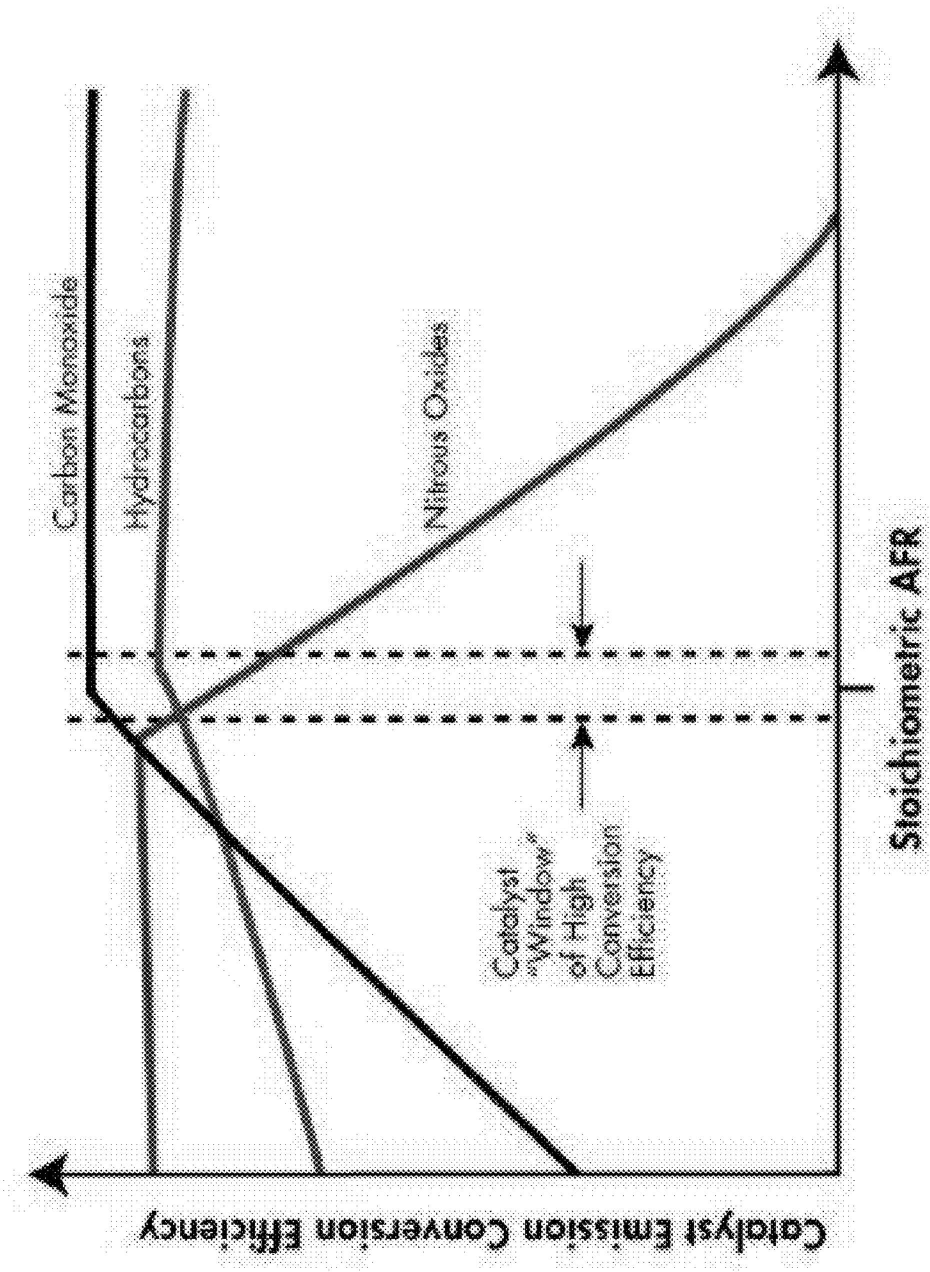

Carbon Monoxide
Hydrocarbons
Nitrous Oxides
Catalyst "Window" of High Conversion Efficiency
Stoichiometric AFR
Catalyst Emission Conversion Efficiency

Fig. 6

METHOD FOR REDUCING NITROGEN OXIDE(S) AND CARBON MONOXIDE FROM FLUE GASES AND FLUE GAS COMPOSITION

PRIORITY

[0001] This application claims priority of the Finnish national application number FI20155279 filed on Apr. 14 2015, the contents of which are incorporated herein by reference in entirety.

FIELD OF THE INVENTION

[0002] The invention relates to a methods and devices to reduce nitrogen oxide(s) and carbon monoxide from flue gasses of industrial burners as well as to flue gas compositions.

[0003] The invention relates to a method as set forth in the claim **1** for reducing nitrogen oxide(s) and carbon monoxide from flue gases of an industrial burner which is intended for a gaseous and/or liquid fuel.

[0004] The invention relates also to a flue gas composition in the claim **17**.

[0005] The invention relates further to burner automation, which can be used in the burner of the invention.

BACKGROUND OF THE INVENTION

[0006] One generally known industrial burner model, which is intended for gaseous and/or liquid fuels, comprises in connection with the windbox a fuel supply conduit for the combustion head and opening to the combustion head, as well as a combustion air supply conduit opening into the windbox. The windbox is associated with a combustion chamber, such as a boiler, which opens into a flue gas conduit.

[0007] The burner operation is controlled by burner automation, comprising measuring instruments which include in particular a lambda sensor that measures the amount of residual oxygen in flue gases.

[0008] In another generally known, so-called monoblock industrial burner, intended for gaseous and/or liquid fuels, the air is supplied directly to the combustion head of a burner with an air blower included in the burner.

[0009] When an industrial burner is used for the combustion of liquid or gaseous fuels, there is a problem that the thermal combustion process always generates nitrogen oxides (NOx) because, at a high temperature (>1000° C.), the atmospheric nitrogen or organic nitrogen contained in fuel reacts with combustion air or oxygen contained in fuel. The higher the temperature and the longer the burn time, the more NOx emissions are produced. Another problem in the thermal combustion process is that thermal combustion is never complete, but the flue gas is always left with unburned hydrocarbons (VOC) and carbon monoxide (CO) as a result of incomplete combustion. The resulting amount of these is the higher, the lower the temperature and the shorter the burn time.

[0010] Therefore, the emissions resulting from reducible (NOx) and oxidizable (HC and CO) reactions are generated in conflicting temperature conditions, hindering the reduction thereof. Authorities have started to introduce stricter emission regulations based i.a. on BAT (Best Available Technology) resolutions in Europe BAC (Best Available Control) standards in the USA.

[0011] One possibility of reducing the amount of emissions is to use catalytic post-combustion known from the Applicant's WO application No. 2014/154931 in connection with the above-described burner by placing a catalytic converter in a combustion chamber, such as a boiler or flue gas conduit, present in association with the burner. In one embodiment of the above-mentioned patent application, the fuel is pre-combusted partially in at least one thermal pre-combustion zone of the burner and thereafter the post-combustion of pre-combustion-generated gases is carried out in at least one post-combustion zone provided with a catalytic converter for burning the pre-combustion-generated gases, for the reduction of pre-combustion-generated NOx's, and/or for the oxidation of hydrocarbon and carbon monoxide emissions. The post-combustion is conducted in at least one catalytic zone. In one embodiment of the above-mentioned application, the apparatus comprises a thermal burner which is supplied with a liquid or gaseous fuel, and the apparatus is further provided with at least one catalytic converter for the reduction of NOx's present in flue gases generated in thermal combustion, as well as for the oxidation of hydrocarbon and carbon monoxide emissions.

[0012] In case the aforesaid burner is adjusted without a feedback from flu gases, the oxygen content of flue gases shall vary roughly +/−1%, which corresponds to about 10% of the amount of combustion air. In a non-feedback system, 3% of residual oxygen (lambda=about 1.15) is in practice the minimum residual oxygen level to which the burner can be adjusted. The excess air of a burner can also be adjusted to a lower level by a feedback of the oxygen measurement conducted from flue gases. With oxygen measurement, the combustion air or fuel of a burner is controlled by burner automation so as to maintain the oxygen content of flue gas at about 2-3%. In addition to oxygen control, it is possible to employ carbon monoxide control which adjusts the residual oxygen to a lower level until small amounts of carbon monoxide begin to appear. This adjustment may enable an achievement of the residual oxygen level close to about 1% (lambda=about 1.05).

[0013] The use of a catalytic post-combustion method as described in the above-mentioned application has been said to require that an approximately stoichiometric air-fuel ratio during the thermal combustion process be maintained consistently.

[0014] It was now unexpectedly discovered in the invention that the stoichiometric fuel and air ratio required by the discussed method is practically unreachable with existing automation and fuel supply solutions in a design, wherein the accompanying flue gas conduit or boiler is provided with a so-called three-way catalytic converter. Even with several possible burner adjustment methods available, there is none that would achieve a sufficiently low residual oxygen level required for flue gases by the method described in the discussed application.

[0015] By just regulating the rate of total fuel flow and total combustion air flow, it will be difficult to reach the required concentrations of residual oxygen prior to the catalytic zone as a result of physical, burner control technology-related, as well as hardware-related limitations.

[0016] Additionally, it was discovered, that while it was sometimes possible to attain stoichiometric fuel and air ratio in a mixer zone of a burner and thereafter a proper flue gas composition before delivering this flue gas composition into catalytic zone with above "existing technology" for example by regulating the air/fuel ratio supplied into a burner conventional technology, "it was practically impossible to maintain said proper composition of flue gases except for a very short time span.

SUMMARY OF THE INVENTION

[0017] With the aforesaid, thus far unrecognized problems as a starting point, it was a main objective of the invention to provide a catalytic converter-equipped industrial burner, in which the above-discussed method is applied and which consistently and continually enables a major reduction of nitrogen oxides NOx, as well as unburned hydrocarbons (VOC) and carbon monoxide (CO), present in flue gases generated in the thermal combustion process of a burner.

[0018] It was a second principal objective of the invention to provide an industrial burner, which has its combustion chamber or flue gas conduit provided with a catalytic converter, and which burner enables a stoichiometric air-fuel ratio to be sustained during thermal combustion.

[0019] One important further objective of the invention relates to a method, which enables the amounts of air and fuel for a burner to be adjusted in a (thermal) combustion process of the burner so as to reach low residual oxygen prior to a catalytic zone.

[0020] The term "industrial burner" in this application refers to an apparatus, which is capable of being connected to a combustion chamber such as a boiler and which comprises all devices needed for a combustion operation and its monitoring. These comprise fuel and air mixers, air supply means, including air blowers that can be incorporated in the burner (a so-called monoblock burner) or separate (a so-called duoblock burner). In this disclosure, the burner is considered to contain a main portion of burner automation such as combustion process monitoring and control devices, including measuring instruments for the composition of flue gases. After the combustion chamber but before the flue gas conduit is usually a heat exchange area. The industrial burner has nominal output at least 3 MWh.

[0021] Present disclosure relates specifically to industrial burner which comprises a fuel and air mixing zone, a fuel supply conduit which is adapted to supply the mixing zone with a given inlet flow of fuel, as well as a combustion air supply means which is adapted to provide the mixing zone with a given inlet flow of combustion air, as well as burner automation which contains measuring instruments. The burner has its mixing zone accompanied by a combustion chamber which is in communication with measuring instruments in a flue gas conduit, said combustion chamber or flue gas conduit being provided with at least two catalytic zones. After the combustion chamber but before the flue gas conduit is a heat exchange area.

[0022] Term "combustion chamber" means herein furnace, combustion chamber or other limited space where combustion with industrial burner takes place.

[0023] Above mentioned objectives can be reached by a method of claim **1**.

[0024] More specifically, the invention relates to a method according to claim **1**, which comprises adjusting the fuel and air ratio in a burner intended for a gaseous and/or liquid fuel.

[0025] The method comprises:

a) providing an industrial burner adapted to burn gaseous and/or liquid fuel, and comprising a burner automation containing measuring instruments (**6**), and a mixing zone accompanied by a combustion chamber, said burner automation being in communication with a measuring instruments of a flue gas conduit, said combustion chamber or flue gas conduit being provided with at least two catalytic zones of at least one three-way catalytic converter(s), which catalytic zones are successive in progressing direction of flue gases;

b) delivering an inlet flow (Q_I, Q_{Itot}) of combustion air and an inlet flow (Q_{PA}, Q_{PAtot}) of fuel into the mixing zone;

c) generating flue gases in the combustion chamber by combusting air and fuel delivered into the mixing zone in step b);

d) measuring the amount of residual oxygen, in flue gases (flue gas oxidation/reduction potential) by a lambda-sensor;

e) directing the flue gases to said at least one three-way catalytic converter(s) (**401**);

f) adjusting the inlet flow (Q_I, Q_{Itot}) of combustion air and the inlet flow (Q_{PA}, Q_{PAtot}) of fuel arriving in the mixing zone in step b) by means of said burner automation, so that the mean amount of residual oxygen (O_2, in moles) compared to mean amount of carbon monoxide (CO, in moles), is 0.5/1 (mole/mole), oxygen being additionally within the range of 0.01-0.50 vol-%, preferably in the range of 0.01-0.25 vol %, in flue gases prior to or at the three-way catalytic converter;

[0026] g) delivering supplementary air between the first and the second catalytic zones of the three-way catalytic converter, or between catalytic zones (**40**, **40**) of two successive three-way catalytic converters, so that concentration in the flue gases after said catalytic zones is within range of 0-9 ppm for NOx and within a range of 0-100 ppm, preferably in the range of 0-40 ppm for CO.

[0027] In the above-discussed method the low amount of residual oxygen of 0.01-0.50%, preferably of 0.01-0.25% in flue gases prior to the catalytic zone is achieved by using a system with feedback for regulating the ratio between a fuel flow arriving in a fuel and air mixing zone, particularly in a combustion head, and a combustion air flow arriving in a windbox present in association with the combustion head. In the system with feedback, the amount of residual oxygen is measured prior to a catalytic zone and the measured residual oxygen is used as a basis for adjusting the air/fuel ratio.

[0028] However, the delay in controlling air/fuel based on O_2/lambda measurement is relatively long due to large volume of combustion chamber and flue gas conduit in an industrial burner (nominal power over 3 MWh). Therefore the present invention contains also step of delivering supplementary air between the first and the second catalytic zones of said at least one three-way catalytic converter (step g above). This adjustment reacts very quickly to variation in O_2/CO-ratio.

[0029] In the preferred method of this disclosure the O_2/lambda measurement for controlling air/fuel rate is performed inside the catalyst. Then the amount of supplementary air supplied between the catalytic zones of said at least one three-way converter is based on measured oxygen amount measured by a lambda-sensor located after the second catalytic zone of said at least one three-way catalytic converter.

[0030] When delivery of combustion air between catalytic zones of a three-way catalytic converter depends of the measured oxygen present after the second catalytic zone the method is very accurate; the measurement of O_2 in flue gases after the three-way catalytic converter is much more accurate compared to situation wherein the O_2 would be measured prior to the first catalytic zone of at least one three-way catalytic converter.

[0031] These both adjustment steps, mentioned above, will bring the concentration of CO and NOx in flue gases before said catalytic converter consistently in a very low level. This consistency and low levels of CO and NOx prior or after catalytic converter has not been achieved before: the measured NOx should be within a range of 0-9 ppm and CO within a range of 0-100 ppm, preferably in the range of 0-40 ppm after the second catalytic zone of three-way catalytic converter(s). The proportion of O_2 to CO should be stoichiometric, about 0.5/1 (mole/mole), oxygen being additionally within the range of 0.01-0.50, preferably in the range of 0.01-0.25 vol % in flue gases prior to or at the first catalytic zone of at least one three-way catalytic converter;

[0032] The above mentioned stoichiometric oxygen/CO-proportion prior to catalytic converter is achieved in a preferred embodiment of the invention by first controlling the air/fuel—proportion in the main inlet flow of fuel. The air/fuel-proportion of this main fuel portion is based on a predetermined amount of residual oxygen in flue gases (preferably 1.0-2.5%). Additionally one should control the amount of second inlet portion of fuel which is based on defining the residual oxygen content of gases prior to the first catalytic zone of—at least one catalytic converter(s) in a combustion chamber or in a flue gas conduit and then adjusting the secondary inlet flow of fuel and combining this second inlet portion to main portion. In this connection it should be noted that defining the oxygen content of flue gases prior to the first catalytic zone can be performed by a lambda sensor located at the catalytic converter, for example after the first catalytic zone.

[0033] Thus the mixing zone, such as a combustion head, may be supplied with a secondary inlet flow of fuel or air, the supply rate of which is in turn based on measuring the amount of residual oxygen prior to first catalytic zone of at least one three-way catalytic converter(s) and on a precise control of the secondary inlet flow rate conducted on the basis of these measurements.

[0034] It is alternatively possible to regulate in a respective manner the rate of a combustion air flow arriving in an windbox (i.e. by dividing the combustion air flow into a primary flow and a secondary flow, with just the secondary flow being regulated in a feedback manner).

[0035] The above mentioned feedback system is achieved by a burner automation which uses so called Smith predictor for adjusting the amount of the ratio of fuel and air arriving to said mixing zone. To be more precise, the Smith predictor adjusts the secondary inlet flow of air or fuel.

[0036] In a more preferred embodiment, the low amount of residual oxygen in flue gases is nevertheless achieved by regulating the delivery of a primary inlet flow of fuel and a flow of combustion air to the flame by setting for these such supply rates that, based on estimates and calculations, it can be presumed that a given predefined amount of residual oxygen (1.0-2.5%) is reached prior to first catalytic zone of the at least one three-way catalytic converter(s) having at least two catalytic zones in successive order

[0037] In addition to this, the mixing zone, such as a combustion head, is supplied with a secondary inlet flow of fuel or air, the supply rate of which is in turn based on measuring the amount of residual oxygen prior to first catalytic zone of at least three-way catalytic converter(s) and on a precise control of the secondary inlet flow rate conducted on the basis of these measurement. Again in this connection it should be mentioned that measurement of residual oxygen before first catalytic zone can be performed also after said first catalytic zone.

[0038] The residual oxygen level prior to first catalytic zone should be kept in the range of 0.01-0.50%, preferably 0.01-0.25% which means that the proportion of O_2 to CO should be stoichiometric or about 0.5/1 (mole/mole).

[0039] As the amount of residual oxygen is reduced in flue gases with the above-described method, as well as with a burner employed therein, there is simultaneously provided a capability of both enhancing efficiency of the burner and of keeping emissions at an extremely low level that is under 0.025% in flue gases prior to the first catalytic zone.

[0040] The level of O_2 in flue gases should be nearly stoichiometric as to amount of CO. The mean level of O_2 in moles (or vol %) compared to mean level of CO in moles (or vol %) should be 0.5/1 and variation of said proportion should be kept in the range of 0.998-1.002. This means, that if the concentration of CO in flue gases is about 6000 ppm, the concentration of O_2 should be correspondingly 1000-4000 ppm and mean value of 02 concentration should be about 3000 ppm.

[0041] This method comprises additionally:

[0042] adjusting the amount of said primary inlet flow by means of burner automation and an actuator-equipped control valve present in a first transfer pipe system, based on a predetermined amount of residual oxygen in flue gases, preferably the amount of 1.0-2.5% residual oxygen in flue gases, and based on a primary inlet flow which is estimated or calculated on the basis thereof and which combines with a total inlet flow of fuel to be delivered to the combustion head by way of the supply conduit, and

[0043] measuring the amount of residual oxygen in flue gases prior or after the first catalytic zone of at least one three-way catalytic converter in a combustion chamber or in a flue gas conduit,

[0044] adjusting the secondary inlet flow of fuel by means of burner automation and an actuator-equipped control valve present in a second transfer pipe system, based on the amount of residual oxygen measured from flue gases, whereby the burner automation adjusts the secondary inlet flow of fuel which combines with a total inlet flow of fuel arriving in the combustion head by way of a supply conduit,

[0045] adjusting the amount of an inlet flow of combustion air arriving in an windbox by means of burner automation and an actuator present in a combustion air transfer pipe system, such that the adjustment of the combustion air inlet flow is based on a predetermined amount of residual oxygen in flue gases, preferably on the amount of 1.0-2.5% residual oxygen in flue gases.

[0046] More specifically, such a preferred method comprises additionally the following steps of:

[0047] the amount of residual oxygen in flue gases is measured upstream or preferably at the said three-way catalytic converter,

[0048] the amount of a combustion air inlet flow (Q_I) arriving at the mixing zone is adjusted by means of burner automation and an actuator present in a combustion air transfer pipe system, such that the adjustment of the combustion air inlet flow (Q_I) is based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases (S),

[0049] the fuel inlet flow arriving at the mixing zone is adapted to consist of two separately adjusted portions (Q_{PAA}, Q_{PAB}) of inlet flow proceeding by way of a fuel transfer pipe system into the supply conduit, whereof the first portion (Q_{PAA}) of inlet flow comprises a primary inlet flow, which is adapted to travel in a first section of the transfer pipe system that is in fluid communication with the supply conduit and which makes up 70-100% of the inlet flow, preferably 80-100% of the (total) inlet flow (Q_{PAtot}), and whereof the second portion (Q_{PAB}) of inlet flow comprises a secondary inlet flow, which is adapted to travel in a second section of the transfer pipe system that is likewise in fluid communication with the supply conduit and which makes up 0-30% of the inlet flow, preferably 0-20% of the inlet flow (Q_{PAtot}), whereby

[0050] the rate of said primary inlet flow (Q_{PAA}) is adjusted by means of burner automation and an actuator-equipped actuator, such as an electric motor-operated control valve, present in a first transfer pipe system, based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases, and on the primary inlet flow (Q_{PAA}) estimated or calculated on the basis thereof, which combines with the total inlet flow (Q_{PAtot}) of fuel to be delivered to the combustion head by way of the supply conduit and

[0051] the secondary inlet flow (Q_{PAB}) of fuel is adjusted by means of burner automation and actuators, such as an actuator-equipped control valve and an actuator-equipped check valve (**7**; **70**), present in a second transfer pipe system, based on the amount of residual oxygen measured from flue gases, by means of which the burner automation adjusts the secondary inlet flow (Q_{PAB}) of fuel which combines with the total inlet flow (Q_{totPA}) of fuel arriving at the combustion head (**1**) by way of the supply conduit,

[0052] the ratio of the (total) inlet flow (Q_{totPA}) of fuel to the combustion air flow (Q_I) arriving in the windbox is maintained such that the amount of residual oxygen is 0.01-0.50% preferably 0.01-0.25%, in flue gases prior to the first catalytic zone of at least one three-way catalytic converter.

[0053] The actuator-equipped control valve is for example a control valve adjustable with an electric motor, pneumatically or hydraulically.

[0054] Accordingly, in the method according to a another embodiment of the invention:

[0055] the adjustment by means of burner automation for a fuel inlet flow arriving in the combustion head by way of a fuel supply conduit and transfer pipe system is based on a predetermined amount of residual oxygen in flue gases, preferably on the amount of 1-2.5% residual oxygen in flue gases, and on the amount of fuel estimated or calculated on that basis and to be delivered to the combustion head, and

[0056] the inlet flow of combustion air arriving in the windbox by way of a combustion air supply conduit is adapted to consist of two separately regulated portions of the inlet flow proceeding into the supply conduit by way of a combustion air transfer pipe system. The first portion of the inlet flow comprises a primary inlet flow, which is adapted to travel in a first section of the transfer pipe system that is in fluid communication with the supply conduit, and which makes up 70-100%, preferably 80-100%, of the inlet flow of combustion air, and whereof the second portion of inlet flow comprises a secondary inlet flow, which is adapted to travel in a second section of the transfer pipe system that is likewise in fluid communication with the supply conduit, and which makes up 0-30%, preferably 0-20%, of the inlet flow of combustion air. Hence,

[0057] the adjustment for the amount of said primary inlet flow of combustion air adapted to travel in the first section of the transfer pipe system takes place by means of burner automation and an actuator, such as an amount control valve, present in the first transfer pipe system, and is based on a predetermined amount of residual oxygen in flue gases, preferably on the amount of 1-2.5% residual oxygen in flue gases, and on the amount of the primary inlet flow of combustion air which is estimated or calculated on the basis thereof and which combines with the inlet flow of combustion air to be delivered to the combustion head by way of the supply conduit, and

[0058] the adjustment for the amount of said secondary inlet flow of combustion air adapted to travel in the second section of the transfer pipe system takes place by means of burner automation and actuators, such as control valves, present in the second transfer pipe system, and is based on the amount of residual oxygen measured from flue gases, by way of which the burner automation adjusts the secondary inlet flow of combustion air, which travels by way of the second section of the transfer pipe system and which combines with the inlet flow of combustion air arriving in the windbox by way of the supply conduit, such that the amount of residual oxygen is 0.01-0.50%, preferably 0.01-0.25%, in flue gases prior to the first catalytic zone of the at least one three-way catalytic converter having at least two catalytic zones or prior to the first catalytic zone of at least two three-way catalytic converters having at least one catalytic zone.

[0059] In the invention, one catalytic converter with at least two catalytic zones or at least two three-way catalytic converter with one catalytic zone, are successive in the traveling direction of flue gases and between said two catalytic zones can be introduced supplementary air by way of an extra supply conduit of air arriving in the flue gas conduit.

[0060] This way, the catalytic converter can be provided with an expanded operating range, such that the flue gas arriving at first catalytic zone can have a lambda of less than 1, specifically 0.95-1.

[0061] In this case, the reduction of nitrogen oxides, as well as the oxidation of hydrocarbon and carbon monoxide emissions, is still adequately effective in the first catalyst regardless of sub-stoichiometric conditions prior to the first catalytic zone, and the remaining unoxidized CO and VOC emissions shall then be oxidized by means of supplementary air in the latter catalyst. As mentioned before the adjustment of level of unoxidized CO and VOC emissions can be performed very quickly in said catalytic converter.

[0062] In another preferred embodiment of the invention, the flue gas comprising O_2, CO, NOx gases which arrives to said first catalytic zone of said at least one catalytic converter(s) have been homogenized by a mixer located in flue gas conduit or in a heat exchange area after burner's combustion chamber for delivering a homogenous flue gas mixture into said catalytic converter. Homogenization of flue gases is needed before they enter the catalytic zone(s) because combustion chamber of and industrial burner is relatively large and therefore there it has a tendency to include pockets of high concentration of CO.

[0063] In yet another preferred embodiment, the ratio of a combustion air flow arriving in the windbox to a fuel flow arriving at the combustion head is adapted to oscillate within a specific steadily constant range. Since the ratio of a fuel flow intended for the flame to a combustion air flow varies from slightly lower than stoichiometric to slightly higher than stoichiometric, there is provided a capability of further expanding the effective operating range of a catalytic converter, i.e. the maximum accepted quantity of residual oxygen prior to a catalytic zone. Preferably, the rate of air flow delivered into a burn zone is maintained constant and the amount of fuel is allowed to oscillate so as converge towards a desired air/fuel ratio.

[0064] In one preferred embodiment, it is possible to have the amount of combustion air I adjusted by one or more blowers present in the transfer pipe system, well as by dampers with adjustable opening degrees or by control valves. In this case, to the blower is preferably connected a frequency transformer that enables an adjustment of the blower motor's input power and thereby the rotational speed of the blower motor, as well as the air flow velocity, depending on a utilization rate of the burner.

[0065] Having the blower equipped with a frequency transformer enables lower amounts of residual oxygen in flue gases to be reached, the burner efficiency to be enhanced, as well as the power consumption of blowers to be reduced.

[0066] In another preferred embodiment, the rate adjustment of a secondary inlet flow of fuel takes place by means of at least one actuator-equipped control valve and at least one actuator-equipped on/off valve.

[0067] The actuator-equipped control valve is for example a valve adjustable with an electric motor, pneumatically or hydraulically.

[0068] Thus, the measuring instruments may include a lambda sensor which measures residual oxygen and which is located upstream (prior) or preferably after the first catalytic zone of the catalytic converter with at least catalytic zones (or after the first catalytic zone of two catalytic converters), and additionally a sensor which measures the amount of nitrogen oxides NOx from flue gases, and/or a sensor which measures the amount of carbon monoxide from flue gases. The NOx as well as CO sensors may be present upstream of downstream of the first catalytic zone of at least one three-way catalytic converter(s. In one implementation of the invention, these are located downstream of the second catalytic zone in a flue gas conduit. In this case, the adjustment of a secondary inlet flow of fuel traveling in a second section of the transfer pipe system is additionally based on the amount of carbon monoxide measured from flue gases and/or on the amount of nitrogen oxides, such that the burner automation regulates, on the basis of nitrogen oxides and carbon monoxide measured from flue gases, the rate of the secondary inlet flow of fuel by means of actuators, such as actuator-equipped control valves, included in the second section of the transfer pipe system.

[0069] This preferred embodiment of the invention provides a capability of further reducing the amount of NOx, CO, and hydrocarbon emissions

[0070] The invention and benefits attainable thereby will now be elucidated further with reference to the accompanying figures.

SHORT DESCRIPTION OF THE DRAWINGS

[0071] FIG. **1** shows schematically one burner of the invention and burner automation employed therein and used for precisely adjusting the amount of fuel.

[0072] FIGS. **2**A and **2**B show likewise schematically another burner of the invention and burner automation employed therein and used for precisely adjusting the amount of combustion air.

[0073] FIG. **3** illustrates flows of combustion air and fuel arriving at a combustion head and in a windbox in the burners of FIGS. **1** and **2**.

[0074] FIG. **4** shows a more detailed view of burner automation employed in a burner of the invention.

[0075] FIG. **5** reveals a test arrangement of a test burner having construction and function according to present invention.

[0076] FIG. **6** shows test results of using optimal three-way catalytic converter.

DETAILED DESCRIPTION

[0077] As can be seen from FIG. **5** shows test results from 2.6 MW capacity industrial burner with applied catalytic flue gas treatment (Oilon laboratory Lahti, Finland). The burner construction and function was similar as defined in claims. As can be seen from FIG. **5** NOx average was through measuring period <2 ppm (dry) and CO average was through measuring period <4 ppm (dry). These results confirm that using the burner of the present invention one can achieve very low NOx and CO emissions.

[0078] FIG. **6** shows a flue gas concentration before a three-way catalytic converter which enables most efficient conversion of NOx and CO in a catalytic zone of said a three-way converter. The following reactions take place in a three-way converter:

[0079] Main oxidation reactions:

$$CO+0.5O_2—CO_2$$

$$CH_4+2O_2\text{-}CO_2+2H_2O$$

[0080] Main reduction reactions:

$$2NO+2CO\text{-}N_2+2CO2$$

$$4NO+CH_4\text{-}2N_2+CO_2+2H_2O$$

[0081] As can be seen from FIG. **6**, air to fuel ratio (a) should be almost stoichiometric in flue gases before a three-way catalytic converter said ratio. The amount of O_2 to mean amount of CO (mole/mole) should be nearly stoichiometric; the mean amount of O_2 (in moles) to mean amount of CO gases (in moles) should be about 0.5/1 mole/mole in flue gases before said flue gases enter the three-way catalytical converter in the flow direction of flue gases.

[0082] This means that if CO concentration in flue gases just before entering catalytic zone of a three-way catalytic converter is typically 3000 ppm, the amount of O_2 may vary 1500 ppm+−1000 ppm. Lambda should be in the range of 0.997-1.003.

[0083] In usual CO-levels in exhaust gases generated by an industrial burner before said three-way converter, said exhaust gases (flue gases) may contain only 0.01-0.50% or even only 0.01-0.025% of O_2 to enable catalytic conversions of CO and NOx to take place optimally in said three-way catalytic converter. In addition, it was detected in a separate test that, in case the amounts of fuel and oxygen were allowed during thermal combustion to oscillate in such a way that the ratio of fuel and combustion air in thermal combustion was alternately sub-stoichiometric and alternately over-stoichiometric, there was provided a capability of increasing the maximum acceptable amount of residual oxygen prior to a catalytic zone so as to allow the presence of 0-0.50% residual oxygen in flue gases prior to the catalytic zone. This means that the amount of residual oxygen is only allowed to be not more than about a half of what has been reached with prior known adjustment methods applied to the ratio of oxygen and combustion air in a burner.

[0084] The stoichiometric O_2/CO-ratio in exhaust gases before a three-way catalytic converter, demanded for an efficient conversion of NOx- and CO-gases cannot be reached by normal industrial burners because this requires nearly stoichiometric air/fuel ratio in burner and strict O_2 levels (0.01-0.50 preferably 0.01-0.25) before the first catalytic zone of at least one three-way catalytic converter.

[0085] FIGS. **1-4** represent a burner and burner automation, providing a capability of reaching, in such a burner, a sufficiently low amount of residual oxygen prior to a catalytic zone of a three-way converter As presented in FIGS. **5** and **6** there should be only 0.01-0.50% more preferably 0.01-0.25% of oxygen in flue gases before the first catalytic zone of at least one three-way catalytic converter.

[0086] FIGS. **1** and **2**A are schematic views of burners according to the invention, wherein is implemented an adjustment of the invention for fuel and combustion air used for regulating the air/fuel ratio arriving in the flame. FIG. **3** shows in turn the fuel and combustion air flows of FIGS. **1** and **2**A.

[0087] FIG. **2**B shows an alternative implementation for a secondary inlet flow of air.

[0088] Next follows a brief survey of the main structures and functions shown in FIGS. **1-3**.

[0089] Each of FIGS. **1** and **2**A shows a burner **100**, which is intended for a gaseous or liquid fuel such as natural gas or fuel oil. The burner **100** comprises a combustion head **1** located in connection with a windbox **10**, physically downstream of said cabinet, as well as a boiler **3** which is associated with the windbox **10** and opens into a flue gas conduit **4**.

[0090] The boiler **3** or the flue gas conduit **4** is provided with two catalytic zones **40**, **40**. In this case, the three-way converter **401** of the boiler **3** or the flue gas conduit **4** comprises two catalytic zones **40**,**40** in two separate three-way catalytic converters (**401**) for the afterburning of gases generated in thermal combustion conducted in the boiler **3**. It is possible to deliver supplementary air into a space between the catalytic zones **40**, **40** of a catalytic converter having at least two catalytic zones or between series of catalytic converters **401** having one catalytic zone each by way of an extra air supply conduit **222**. The catalytic converter **401** is a three-way catalytic converter, which is selected in view of being suitable for the catalytic burning of combustion gases and for the reduction of NOx's generated in thermal combustion conducted with the combustion head **1** and the windbox **10** associated therewith and for the oxidation of hydrocarbon as well as carbon monoxide emissions in resulting flue gases.

[0091] By delivering supplementary air between the first and the second catalytic zones of at least one three-way catalytic converter one can adjust very quickly to variation in the amount of NOx and CO in the flue gas arriving said catalyst.

[0092] In addition, the burner **100** includes burner automation **5**, **6**, **7** whose operation is more closely illustrated in FIG. **4**.

[0093] As can be seen from FIGS. **1** and **2**A, it is possible that the flue gas conduit **4**, upstream of the catalytic zone **40** in the flowing direction of flue gas S, be supplied with combustion air I by way of an opening in a wall of the flue gas conduit **4**. If desired, it is by way of the flue gas conduit that the exterior of the flame could also be supplied with fuel PA. In the burners shown in FIGS. **1** and **2**A, the catalytic zone **40** comprises two three-way catalytic converters **401**, which are successive in the traveling direction of flue gases and which enable oxides of nitrogen to be reduced, as well as unburned hydrocarbons (VOC) and carbon monoxide (CO) to be oxidized. It is possible that into a space between these is introduced supplementary air by way of an extra air supply conduit **222**.

[0094] In FIGS. **1** and **2**A is presented also a mixer after the combustion chamber in the flue gas conduit before the catalytic zone of the first three-way catalytic converter, in the flow direction of flue gases. This mixer is intended for acquiring a homogenized flue gas mixture before delivering it to said catalytic converter. In FIG. **7** is presented one possible static mixer structure.

[0095] In FIGS. **1**, **2**A and **4** can also be seen a central unit **5** of burner automation and measuring instruments **6** for collecting information about the combustion process to be controlled, as well as various actuators **7** which are controlled by the burner automation. In burners **100** visible in FIGS. **1** and **2**, the measuring instruments **6** include at least a plurality of lambda sensors **63**; $\mathbf{63}^1$, $\mathbf{63}^2$, $\mathbf{63}^3$, $\mathbf{63}^4$, which measure the amount of residual oxygen in flue gases (the oxidation/reduction potential of flue gas) and which are located upstream and downstream of the two three-way catalytic converters **401**, **401** with one catalytic zone **40** each. There are also two lambda sensors between said catalytic zones **40**, **40** and the first is just before said extra air supply conduit **222** opening between catalytic zones **40**, **40** in an arrow-indicated traveling direction of the flue gases S. The measuring instruments **6** further include sensors **61**; $\mathbf{61}^1$, $\mathbf{61}^2$, which are located downstream of both catalytic zones **40**,**40** in a traveling direction of the flue gases S and which measure the amount of nitrogen oxides NOx from flue gases, and/or sensors **62**; $\mathbf{62}^1$, $\mathbf{62}^2$ which measure the amount of carbon monoxide from flue gases. These sensors are located downstream of the catalytic zones **40**,**40** in the flowing direction of flue gases and, as a result, are used for measuring NOx and CO emissions in the flue gas conduit **4** after the catalytic converters **401**.

[0096] It is by way of a supply conduit **210** for fuel PA, opening onto the combustion head **1**, that the combustion head **1** is supplied with a given fuel inlet flow Q_{PA}, or Q_{PAtot}

(cf. FIG. **3**), i.e. a given volume flow of fuel per unit time. On the other hand, it is a supply conduit **220** for combustion air I that supplies the windbox **10** with a given combustion air inlet flow Q_I, or Q_{Itot}, i.e. a given volume flow of combustion air per unit time.

[0097] In the burner **100** according to a first embodiment of the invention, shown in FIG. **1**, the combustion head **1** is supplied by way of a fuel supply conduit **210** with a total fuel inlet flow Q_{totPA}. The total inlet flow Q_{totPA} consists of two separately adjusted inlet flow portions Q_{PAA}, Q_{PAB} (cf. FIGS. **1** and **3**), which proceed by way of separate fuel transfer pipe systems **215**, **216** into the supply conduit **210**.

[0098] The first inlet flow portion Q_{PAA} comprises a so-called primary inlet flow, which is adapted to travel in a first section **216** of the transfer pipe system that is in fluid communication with the supply conduit **210**, and which makes up 70-100% of the inlet flow, preferably 80-100% of the total inlet flow Q_{totPA}. The primary inlet flow Q_{PAA} has its rate regulated with an actuator-equipped control valve, such as with a servo motor-operated control valve **7**; **71**.

[0099] The second inlet flow portion comprises a secondary inlet flow Q_{PAB}, which is adapted to travel in a second section **215** of the transfer pipe system that is likewise in fluid communication with the supply conduit **210**, and which makes up 0-30% of the total inlet flow, preferably 0-20% of the total inlet flow Q_{totPA} (cf. FIGS. **1**, **3**). The rate adjustment for the secondary inlet flow Q_{PAB} of fuel in the second section **215** of the transfer pipe system takes place by means of at least one actuator-equipped control valve **7**; **71**, and further preferably by means of at least one actuator-equipped on/off valve **7**; **70** such as a magnet-operated on/off valve. In an implementation of the invention shown in FIG. **1**, the secondary inlet flow Q_{PAB} has its rate regulated with two servo motor-operated control valves **7**; **71** and with one on/off solenoid valve (check valve) **7**; **70**.

[0100] In an exemplary embodiment of the invention shown in FIG. **1**, the combustion air proceeds by way of a transfer pipe system **229** and a supply conduit **220** into the windbox **10**. It is possible to regulate the amount of combustion air arriving in the windbox **10** with one or more blowers **7**; **72**, as well as with dampers **7**; **73** having an adjustable opening degree. To the blower **7**; **72** in the transfer pipe system **229** is connected a frequency transformer by which the rotational speed of the blower can be adjusted, depending on the blower utilization degree, i.e. on the rate of a combustion air flow Q_I, Q_{Itot} to be delivered into the windbox. Visible in FIG. **1** is also a supplementary air transfer pipe system **222** by which it is possible to introduce supplementary air between catalytic zones **40**, **40** of the flue gas conduit **4** into a space between two catalytic converters **401** and **401** The introduction of supplementary air in the transfer pipe system **222** is regulated with the actuator-equipped control valve **7**; **71**, as well as with the blower **7**; **72** which is located in the air flowing direction downstream thereof and which can be fitted with an inverter.

[0101] The burner according to the exemplary embodiment shown in FIG. **1** is adjusted as follows.

[0102] The amount of a combustion air inlet flow QI arriving in the windbox **10** is regulated with burner automation **5**, **6**, **7** (cf. FIG. **4**), and particularly with one or more blowers **7**; **72** present in a combustion air transfer pipe system **229**, as well as with dampers **7**; **73** having an adjustable opening degree. The adjustment of the combustion air inlet flow Q_I is based on a predetermined amount of residual oxygen O_2 in flue gases S, preferably on the amount of 1-2.5% residual oxygen in flue gases S. This indicates that the adjustment of the amount of combustion air is based on estimating or determining by way of calculation how much combustion air should be introduced when, with a given utilization rate of the burner, it is desirable to reach the amount of 1-2.5% residual oxygen in flue gas prior to the first catalytic zone **40** of at least two catalytic zones.

[0103] The amount of a primary inlet flow Q_{PAA} of fuel is regulated by means of burner automation **5**, **6**, **7** and an actuator-equipped control valve, such as an electric motor-operated control valve **7**; **71**, present in a first transfer pipe system **116**, likewise on the basis of a predetermined amount of residual oxygen in flue gases S, preferably on the amount of 1-2.5% residual oxygen in flue gases. This indicates that the adjustment of the primary inlet flow Q_{PAA} of fuel is based on estimating or determining by way of calculation how much fuel should be introduced with a given utilization rate of the burner when it is desirable to reach the amount of 1-2.5% residual oxygen in flue gas prior to said first catalytic zone **40**.

[0104] The secondary inlet flow Q_{PAB} of fuel is regulated by means of burner automation **5**, **6**, **7** and actuators **7** present in a second transfer pipe system **215**, i.e. by way of two actuator-equipped control valves such as servo motor-operated control valves **7**; **71** and one actuator-equipped on/off valve such as an on/off solenoid valve **7**; **70** present in a section of the transfer pipe system **215**.

[0105] The adjustment of the secondary inlet flow Q_{PAB} of fuel is based on the amount of residual oxygen measured with a lambda sensor **63** from flue gases, by way of which the burner automation **5**, **6**, **7** regulates the secondary inlet flow Q_{PAB}, of fuel, which combines with a total inlet flow Q_{PAtot} of fuel arriving by way of a supply conduit **210** at the combustion head **1**, such that the ratio of the (total) inlet flow Q_{PAtot} of fuel arriving at the combustion head **1** to the combustion air flow Q_{PAB}, arriving in the windbox is such that said amount of residual oxygen is 0.01-0.50%, preferably 0.01-0.25%, in flue gases S prior to the catalytic zone **40** of said first three-way converter **401**.

[0106] The burner embodiment shown in FIG. **2**A differs from that presented in FIG. **1** principally in the sense that this time the combustion air inlet flow Q_{Itot}, arriving in the windbox **10** by way of a combustion air supply conduit **220**, is adapted to consist of two separately adjusted portions of inlet flow Q_{IA}, Q_{IB} proceeding by way of a combustion air transfer pipe system **225**, **226** into the supply conduit **220**. The total combustion air flow Q_{totI}, arriving in the windbox **10**, is now composed the same way as the total inlet flow Q_{totPA} of fuel in the exemplary embodiment of FIG. **1**, i.e. consists of two separate combustion air flows, just one of which, i.e. the secondary inlet flow of combustion air, is adjusted in a manner involving feedback.

[0107] The first portion Q_{IA} of a combustion air inlet flow comprises a primary inlet flow Q_{IA} of combustion air, which is adapted to travel in a first section **226** of the transfer pipe system that is in fluid communication with the supply conduit **220**, and which makes up 70-100%, preferably 80-100%, of the combustion air inlet flow Q_{totI}. The rate adjustment for the primary inlet flow Q_{IA} of combustion air takes place by means of burner automation **5**, **6**, **7** (cf. FIG. **4**) and an actuator **7**, such as an actuator-equipped control valve, for example a servo motor-operated control valve **7**; **71**, present in the first transfer pipe system.

[0108] The second portion Q_{IB} of a combustion air inlet flow comprises a secondary inlet flow, which is adapted to travel in a second section **226** of the transfer pipe system that is in fluid communication with the supply conduit **220**, and which makes up 0-30%, preferably 0-20%, of the combustion air inlet flow Q_{Itot}. The rate adjustment for the secondary inlet flow Q_B of combustion air takes place by means of burner automation **5**, **6**, **7** and actuators **7** present in the second transfer pipe system **225**.

[0109] In an implementation of the invention shown in FIG. **2**A, the rate adjustment for the secondary inlet flow Q_{IB} of combustion air traveling in a line **215** takes place reversely to the adjustment of the secondary inlet flow Q_{PAB} of fuel. The adjustment of the secondary inlet flow Q_{IB} of combustion air is based on a procedure that, in order to attain a stoichiometric ratio between fuel and oxygen, the secondary inlet flow Q_B of air is restricted in normal condition with an appropriate actuator **7**, such as an actuator-equipped control valve or a damper, constricting the secondary inlet flow Q_B of combustion air, and the secondary inlet flow Q_{IB} is returned to an intake side of the blower **7**; **72**.

[0110] The adjustment of a (primary) inlet flow Q_{IA} of combustion air is similar to the adjustment of a fuel inlet flow Q_{PA} shown in the exemplary embodiment of FIG. **1**. Thus, the adjustment is based on estimating or determining by way of calculation how much the combustion air inlet flow Q_{IA} to the combustion head **1** should be with a given burner utilization rate in order to attain the amount of 1-2.5% residual oxygen in flue gases prior to the catalytic zone **40** of the first three-way catalytic converter **40** in the direction of propagating flue gases.

[0111] On the other hand, the adjustment of a secondary inlet flow Q_B of combustion air is based on the amount of residual oxygen, which has been measured or for flue gases S prior to the first catalytic zone **40**, and by way of which the burner automation **5**, **6**, **7** regulates the secondary inlet flow Q_{IB}, of combustion air which travels through the second transfer pipe system **225** and which changes the amount of a combustion air inlet flow Q_{Itot} arriving in the windbox **10** by way of a supply conduit **220**.

[0112] The secondary combustion air inlet flow Q_{IB} can be adjusted for example in such a way that the amount of combustion air, returned in normal condition by way of the second transfer pipe system **225** to an intake side of the blower **7**; **72**, will be constricted with an appropriate actuator **7** present in the transfer pipe system. Such an actuator can be for example an extra damper **7**; **73** shown in the exemplary embodiment of FIG. **2**A.

[0113] There are also other options for constricting the amount of combustion air in the second transfer pipe system **225**, whereby the second transfer pipe system **225** may include for example a return branch **225'** used for returning air by way of an appropriate actuator-equipped control valve **7**; **71** to the intake side of a blower **7**; **72** present in a main line **229**, as shown in FIG. **2**B.

[0114] In a minor malfunction, the amount of air traveling by way of the transfer pipe system **225** is increased by increasing constriction of the secondary inlet flow Q_{IB}.

[0115] Therefore, the adjustment of the secondary inlet flow Q_{IB} of combustion air is based on the amount of residual oxygen measured with lambda sensors **63** from flue gases S upstream of the catalytic zone **40** of the first catalytic converter (in the traveling direction of flue gases). Preferably residual oxygen is measured after the first catalytic zone.

[0116] Based on this, the burner automation **5**, **6**, **7** regulates the secondary inlet flow Q_{IB} of combustion air, which changes the amount of a total inlet flow Q_{totI} of combustion air arriving in the windbox **10** by way of a supply conduit **220**. The adjustment takes place in such a way that the ratio of the (total) inlet flow Q_{totI} of combustion air (secondary inlet flow Q_{IB} of combustion air+primary inlet flow Q_{IA} of combustion air) to the total inlet flow Q_{PA} of fuel arriving at a combustion head remains to be such that the measured amount of residual oxygen is 0.01-0.50% preferably 0.01-0.25% in flue gases S upstream of the first catalytic zone **40**.

[0117] The exemplary embodiments of both FIG. **1** and FIG. **2** are provided not only with lambda sensors **63** located upstream, downstream, upstream or at the three-way catalytic converters **401**, **401** but also with CO sensors measuring the amount of carbon monoxides as well as with NOx sensors **61** measuring the amount of nitrogen oxides NOx in a flue gas conduit **4** downstream of both three-way catalytic converters **401** in the traveling direction of flue gases. The measurements conducted with these CO and NOx sensors **61**, **62** provide a basis for further specifying the rates of the secondary inlet flows Q_{PAB} and Q_{IB} of fuel or combustion air in respective transfer pipe systems **215**, **225**.

[0118] The burner automation according to the invention is in turn elucidated by FIG. **4**.

[0119] The burner **100** according to the invention is provided with integrated burner automation. The burner automation comprises a central processing unit **5**, measuring instruments **6**, and data transfer elements for providing appropriate control instructions **710** for operating actuators **7** which control the supplies of fuel PA and combustion air I for the burner **100**.

[0120] The central processing unit comprises a processor **52** and at least one memory element **51**. The memory elements **51** contain various software products **510** for controlling the burner operation, especially for adjusting the total amounts Q_I, Q_{Itot}, Q_{PA}, Q_{totPA} of air and fuel as well as for regulating the primary and secondary inlet flows Q_{PAA}, Q_{PAB}, Q_{IA}, Q_{IB} of fuel or air by means of respective actuators present in transfer and supply pipe systems. FIG. **4** displays software products **510^1-510^9**, which are used for adjusting respectively the actuators visible in FIGS. **1**, **2** and **4** by way of control instructions **710^1-710^9**.

[0121] The software products **510^1-510^4** are associated with control instructions **710^1-710^4**, which are used for controlling the supply of air I to the windbox **10** and a supplementary inlet flow in a pipe system **222** into the flue gas conduit **4** by way of actuators **7**. In the exemplary embodiment according to FIG. **1**, the supply of combustion air to the windbox **10** is controlled by a blower **7**; **72** as well as by a damper **7**; **73** by way of control instructions **710^4** as well as **710^1**, and the air supply of the supplementary air inlet flow in the transfer pipe system **222** into the flue gas conduit **4** is controlled by an actuator-equipped control valve **7**; **71** as well as an inverter-controlled blower **7**; **72** by way of control instructions **710^2** and **710^3**.

[0122] The software products **510^5-510^8**, on the other hand, are associated with control instructions **710^5-710^8** to be established for adjusting the supply of fuel PA by way of respective actuators **7**. In the exemplary embodiment according to FIG. **1**, the control instruction **710^8** is used for adjusting a control valve **7**; **71** in a section **216** of the transfer pipe system for the primary inlet flow Q_{PAA} of fuel (FIG. **1**) or an actuator-equipped control valve **7**; **71** in a transfer pipe system **219** for the total inlet flow Q_{PA} (FIG. **2**).

[0123] The control instructions $\mathbf{710^5}$, $\mathbf{710^6}$, $\mathbf{710^7}$, on the other hand, are used for adjusting the secondary inlet flow Q_{PAB} of fuel by way of actuators **7** present in a second section **215** of the transfer pipe system. Said actuators of the transfer pipe system's section **215** include two actuator-equipped control valves **7**; **71** and one actuator-equipped on/off check valve **7**; **70**.

[0124] The control instruction $\mathbf{710^9}$ is generated by software products $\mathbf{510^9}$ associated with the supply of combustion air. These software products and control instructions are related to the adjustment of a secondary inlet flow Q_{PIB} of combustion air. The adjustment of secondary inlet flow is elucidated in the exemplary embodiments of FIGS. **2**A and **2**B in a second section **225** of the transfer pipe system for combustion air. The adjustment takes place by way of an actuator **7**, such as a damper **7**; **73** (FIG. **2**A), or by way of a return line **225'** and an actuator-equipped control valve **7**; **71** (FIG. **2**B), as described above.

[0125] The measuring instruments **6** of burner automation are used for gathering information about the combustion process of a burner **100**. Visible in an embodiment of the invention shown, in FIG. **4** are lambda sensors **63**; $\mathbf{63^1}$, $\mathbf{63^2}$, $\mathbf{63^3}$, **634** measuring residual oxygen, CO sensors **62**; $\mathbf{62^1}$, 62^2 measuring the amount of carbon monoxides, as well as NOx sensors **61**; $\mathbf{61^1}$, 61^2 measuring the amount of nitrogen oxides NOx. The lambda sensors **63** are located upstream, downstream or at the three-way catalytic converters **401**, **401** each with one catalytic zone in the traveling direction of flue gases S, the carbon monoxide sensors **62** as well as the nitrogen oxide sensors **61** being present downstream of the second catalytic zone **40** of the second catalytic converter.

[0126] The data transfer elements are used for collecting measurement data from the measuring instruments **6** and for communicating the same to a processor **52** of the central processing unit **5** and to software products **510**, comprising the reception of a data item regarding the amount of residual oxygen O_2 from the lambda sensors **63**; $\mathbf{63^1}$-$\mathbf{63^4}$ which are present in flue gases and measure the oxidation/reduction potential of a flue gas and from the CO sensors **62**; $\mathbf{62^1}$, $\mathbf{62^2}$ which measure the amount of carbon monoxides, as well as from the NOx sensors **61**; $\mathbf{61^1}$, $\mathbf{61^2}$ which measure the amount of nitrogen oxides NOx.

[0127] The transfer elements supply the processor **5**; **52** as well as the burner control software **510** with the measurement data collected from the sensors **6**. The burner control software **510** as well as the central processing unit **5** provide control instructions **710** for actuators **7** used for regulating the amount of air I and fuel PA.

[0128] In one preferred exemplary embodiment of the invention, which illustrated by FIG. **1**, the central processing unit **52** is adapted by way of the burner control software **510** to generate control instructions as follows:

[0129] 1) the control instructions $\mathbf{710^5}$, $\mathbf{710^6}$, $\mathbf{710^7}$ relating to the amount of a secondary fuel inlet flow Q_{PAB} and used for regulating the secondary fuel inlet flow Q_{PAB} in such a way that the amount of secondary inlet flow Q_{PAB} in a fuel inlet flow Q_{totPA} to be delivered to a combustion head (**1**) is such that the amount of residual oxygen is 0.01-0.50%, preferably 0.01-0.25% in flue gases prior to first catalytic zone **40** of at least two catalytic zones.

[0130] These control instructions $\mathbf{710^5}$, $\mathbf{710^6}$, $\mathbf{710^7}$ are used for controlling the operation of actuators which regulate the rate of a secondary fuel inlet flow. The actuators are located in a pipe system **215** for the secondary inlet flow, and these include for example an actuator-equipped control valve **7**; **71** such as a servo motor-operated control valve, as well as an actuator-equipped on/off valve such as an on/off solenoid valve **7**; **70** (a check valve).

[0131] 2) the control instructions $\mathbf{710^8}$ relating to the amount of a primary fuel inlet flow Q_{PAA} and based on a predetermined amount of residual oxygen in flue gases S, preferably on the amount of 1-2.5% residual oxygen in flue gases **40**.

[0132] The control instruction $\mathbf{710^8}$ is used for controlling the operation of an actuator **7** which regulates the amount of primary inlet flow with an actuator-equipped control valve **7**; **71**, such as a servo motor-operated control valve.

[0133] 3) the control instructions $\mathbf{710^1}$, $\mathbf{710^4}$ used for the inlet flow of combustion air I and for regulating the amount of a combustion air inlet flow Q_I arriving in an windbox **10** by way of a combustion air supply conduit **220**, based on a predetermined amount of residual oxygen in flue gases S, preferably the amount of 1-2.5% residual oxygen in flue gases.

[0134] The control instructions $\mathbf{710^1}$, $\mathbf{710^4}$ are used for controlling by way of actuators **7** the amount of combustion air I arriving in the windbox **10**, said actuators being preferably a blower **7**; **72** as well as a damper **7**; **73**, the former regulating said amount of combustion air in a combustion air transfer pipe system **229** and being fitted with an inverter.

[0135] The invention encompasses also the following examples:

[0136] 1. A method for reducing nitrogen oxide(s) and carbon monoxide from flue gases of an industrial burner (**100**), said method comprising the steps of:

[0137] a) providing an industrial burner (**100**) adapted to burn gaseous and/or liquid fuel, and comprising a burner automation containing measuring instruments (**6**), and a mixing zone accompanied by a combustion chamber, said burner automation being in communication with measurement instruments of flue gas conduit, said combustion chamber or flue gas conduit being provided with two catalytic zones of at least one three-way catalytic converter(s), which catalytic zones (**40**, **40**) are successive in progressing direction of flue gases;

[0138] b) delivering an inlet flow (Q_I, Q_{Itot}) of combustion air and an inlet flow (Q_{PA}, Q_{PAtot}) of fuel into the mixing zone;

[0139] c) generating flue gases in the combustion chamber by combusting air and fuel delivered into the mixing zone in step b);

[0140] d) measuring the amount of residual oxygen, in flue gases (flue gas oxidation/reduction potential) by a lambda-sensor;

[0141] e) directing the flue gases to said at least one three-way catalytic converter(s) (**401**);

[0142] f) adjusting the inlet flow (Q_I, Q_{Itot}) of combustion air and the inlet flow (Q_{PA}, Q_{PAtot}) of fuel arriving in the mixing zone in step b) by means of said burner automation, so that the mean amount of residual oxygen in moles compared to mean amount of carbon monoxide in moles, is 0.5/1 (mole/mole) and O_2 within the range of 0.01-0.50

vol-% preferably in the range of 0.01-0.25 vol % in flue gases prior to or at the first catalytic zone of said at least one three-way converter;

[0143] g) delivering supplementary air between the first and the second catalytic zones (**40**, **40**) of the three-way converter (**401**) or between catalytic zones (**40**, **40**) of two successive three-way catalytic converters, so that concentration in the flue gases after said catalytic zones (**40**, **40**) is within range of 0-9 ppm for NOx and within a range of 0-100 ppm preferable in the range of 0-40 ppm for CO.

[0144] 2. A method defined in example 1 wherein the delivery of supplementary air is based on lambda measurement after the first catalytic zone (**40**) of at least one three-way catalytic converter (s) (401).

[0145] 3. A method defined in example 1 wherein the catalytic three-way converter reduces oxides of nitrogen (NOx) to nitrogen (N_2) and oxygen (O_2) and oxidizes hydrocarbons (HC) and carbon monoxide (CO) to carbon dioxide (CO_2) and water (H_2O).

[0146] 4. The method defined in example 1 wherein the flue gas comprising O_2, CO, NOx gases which arrives to the first catalytic zone of said at least one catalytic converter (**401**) has been homogenized by a mixer located prior to said first catalytic zone (**40**) in the flue gas conduit or in heat exchange area.

[0147] 5. The method defined in example 1 wherein flue gas comprises prior the three-way catalytic converter O_2 in the range of 0.01-0.50 preferably in the range of 0.01-0.25%, CO under 6000 ppm, NOx under 100 ppm and the mean proportion of O_2 to CO is 0.5 mole/1 mole.

[0148] 6. The method defined in example 1 wherein the amount of residual CO and NOx is measured from flue gases and measured NOx concentration is within a range of 0-9 ppm and measured CO concentration within a range of 0-100 ppm preferable within the range of 0-40 ppm and wherein the CO sensor that measures the amount of carbon monoxides, as well as the NOx sensor that measures the amount of nitrogen oxides (NOx), are located downstream of the catalytic zones (**40**,**40**) of the at least one three-way catalytic converter(s) (**401**) in the flowing direction of flue gases (S).

[0149] 7. The method defined in example 1, wherein the amount of residual oxygen in flue gases arriving to said three-way catalytic converter is 0.01-0.25%, measured downstream or at the first catalytic zone (**40**) of said catalytic converter (s) by a lambda-sensor.

[0150] 8. The method defined in example 7, wherein the amount of residual oxygen in flue gases has been measured by a lambda-sensor located between first and second catalytic zones (**40**, **40**) but before the delivery of supplementary air between said two catalytic zones (**40**, **40**).

[0151] 9. The method defined in example 1 wherein the ratio of fuel (PA) delivered to the combustion head (**1**) compared to the combustion air (I) delivered into the windbox (**10**) is adapted to be almost stoichiometric, i.e. within the lambda range of 0.998-1.002.

[0152] 10. The method defined in any of the previous examples wherein the method further comprises adjusting the amount of fuel and air arriving in said mixing zone by adapting the ratio of a combustion air flow (Q_I, Q_{Itot}) arriving in a mixing zone to a fuel flow (Q_{PA}, Q_{PAtot}) arriving by way of a fuel supply conduit (**210**) to be to be such that the amount of residual oxygen is within the range of 0.01-0.25%, in flue gases prior to said first catalytic zone (**40**) of at least one three-way catalytic converter(s).

[0153] 11. A method according to example 10, characterized in that the ratio of the combustion air flow (Q_I, Q_{Itot}) arriving in a mixing zone, such as the combustion head (**1**), to the fuel flow (Q_{PA}, Q_{PAtot}) arriving in a mixing zone, such as the combustion head (**1**), is adapted to oscillate within a certain constantly steady range, preferably by adapting the amount of the combustion air flow (Q_I, Q_{Itot}) to remain constant and by causing the amount of the fuel flow (Q_{PA}, Q_{PAtot}) to oscillate within a certain range so as to approach a desired ratio of the combustion air flow (Q_I, Q_{Itot}) arriving in the mixing zone with respect to the fuel flow (Q_{PA}, Q_{PAtot}) arriving in the mixing zone.

[0154] 12. A method according to example 1 wherein

[0155] the amount of residual oxygen in flue gases is measured upstream or preferably at the said three-way catalytic converter,

[0156] the amount of a combustion air inlet flow (Q_I) arriving at the mixing zone is adjusted by means of burner automation (**5**, **6**, **7**) and an actuator (**7**) present in a combustion air transfer pipe system, such that the adjustment of the combustion air inlet flow (Q_I) is based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases (S),

[0157] the fuel inlet flow arriving at the mixing zone is adapted to consist of two separately adjusted portions (Q_{PAA}, Q_{PAB}) of inlet flow proceeding by way of a fuel transfer pipe system into the supply conduit, whereof the first portion (Q_{PAA}) of inlet flow comprises a primary inlet flow, which is adapted to travel in a first section (**216**) of the transfer pipe system that is in fluid communication with the supply conduit (**210**) and which makes up 70-100% of the inlet flow, preferably 80-100% of the (total) inlet flow (Q_{PAtot}), and whereof the second portion (Q_{PAB}) of inlet flow comprises a secondary inlet flow, which is adapted to travel in a second section (**215**) of the transfer pipe system that is likewise in fluid communication with the supply conduit (**210**) and which makes up 0-30% of the inlet flow, preferably 0-20% of the inlet flow (Q_{PAtot}), whereby

[0158] the rate of said primary inlet flow (Q_{PAA}) is adjusted by means of burner automation (**5**, **6**, **7**) and an actuator-equipped actuator (**7**), such as an electric motor-operated control valve (**7**; **71**), present in a first transfer pipe system, based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases, and on the primary inlet flow (Q_{PAA}) estimated or calculated on the basis thereof, which combines with the total inlet flow (Q_{PAtot}) of fuel to be delivered to the combustion head by way of the supply conduit (**210**), and

[0159] the secondary inlet flow (Q_{PAB}) of fuel is adjusted by means of burner automation (**5**, **6**, **7**) and actuators (**7**), such as an actuator-equipped control valve (**7**; **71**) and an actuator-equipped check valve (**7**; **70**), present in a second transfer pipe system, based on the amount of residual oxygen measured from flue gases, by means of which the burner automation (**5**, **6**, **7**) adjusts the secondary inlet flow (Q_{PAB}) of fuel which combines with the total inlet flow (Q_{totPA}) of fuel arriving at the combustion head (**1**) by way of the supply conduit (**210**),

[0160] the ratio of the (total) inlet flow (Q_{totPA}) of fuel to the combustion air flow (Q_I) arriving in the windbox is maintained such that the amount of residual oxygen is 0.01-0.25%, in flue gases prior to the first catalytic zone of said at least one three-way converter.

[0161] 13. The method defined in example 1 wherein the measuring instruments (**6**) include at least one sensor (**63**), such as a lambda sensor, measuring the amount of residual oxygen in flue gases (flue gas oxidation/reduction potential), said method further comprising following steps of:

[0162] adjusting an inlet flow (Q_I) of combustion air (I) arriving in the mixing zone said adjustment basing on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases (S), and on the amount of combustion air (I) estimated or calculated on the basis thereof and to be delivered to the mixing zone, and

[0163] the fuel inlet flow ($_{totPA}$) is arranged to arrive in the mixing zone by way of the fuel supply conduit (**210**) so that it consist of two separately regulated portions (Q_{PAA}, Q_{PAB}) of the fuel inlet flow, whereof the first portion (Q_{PAA}) of the inlet flow comprises a primary inlet flow which makes up 70-100% of the inlet flow, preferably 80-100% of the inlet flow, and whereof the second portion (Q_{PAB}) of the inlet flow comprises a secondary inlet flow which makes up 0-30% of the inlet flow, preferably 0-20% of the inlet flow, whereby

[0164] the adjustment of said primary inlet flow (Q_{PAA}) of fuel by means of burner automation (**5**, **6**, **7**) is based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases, and on the amount of the primary inlet flow (Q_{PAA}) which is estimated or calculated on the basis thereof in the inlet flow ($_{totPA}$) of fuel (PA) to be delivered to the combustion head, and

[0165] the adjustment of said secondary inlet flow (Q_{PAB}) of fuel, by means of the burner automation (**5**, **6**, **7**), is based on the amount of residual oxygen measured from flue gases (S), by way of which the burner automation (**5**, **6**, **7**) adjusts the amount of the secondary inlet flow (Q_{PAB}) in the inlet flow (Q_{totPA}) of fuel to be delivered to the combustion head (**1**) such that the, so that the mean amount of residual oxygen in moles compared to mean amount of carbon monoxide in moles is 0.5/1 (mole/mole) wherein and amount of residual oxygen is within the range of 0.01-0.25% in flue gases prior to the first catalytic zone (**40**) of at least one three-way catalytic converter(s).

[0166] 14. The method of example 13, wherein the measurement of the amount of residual oxygen of flue gases (S) prior to the first catalytic zone of at least one three-way catalytic converter(s), is performed by a lambda-sensor located after said first catalytic zone and the burner automation (**5**, **6**, **7**) adjusts the amount of the secondary inlet flow (Q_{PAB}) in the inlet flow (Q_{totPA}) of fuel to be delivered to the combustion head (**1**) on the basis of said residual oxygen measurement.

[0167] 15. The method of example 14, wherein additionally the amount of supplementary combustion air supplied between the first and the second catalytic zones (**40**, **40**) of said at least one three-way converter (**401**) is based on measured oxygen amount which measurement is performed by a lambda-sensor located after said second catalytic zone of said at least one three-way catalytic converter.

[0168] 16. A flue gas composition, in a space defined by walls of combustion chamber or a flue gas conduit immediately after a three-way catalytic converter of an industrial burner said flue gas composition comprising, CO and NOx gases in which NOx concentration is in the range of 0-9 ppm, CO within a range of 0-40 ppm and wherein said flue gas composition have been made by:

[0169] (a) providing an industrial burner (**100**) adapted to burn gaseous and/or liquid fuel and comprising a burner automation containing measuring instruments (**6**), and a mixing zone accompanied by a combustion chamber which is in communication with a flue gas conduit, said combustion chamber or flue gas conduit being provided with at least one three-way catalytic converter having at least two catalytic zones (**40**, **40**) or with at least two three-way catalytic converters (**401**, **401**) which are successive in the progressing direction of flue gases and each converter (**401**) having at least one catalytic zone (**40**), which flue gases comprise O_2, CO, NOx gases and are generated by

[0170] b) delivering an inlet flow (Q_I, Q_{Itot}) of combustion air and an inlet flow (Q_{PA}, Q_{PAtot}) of fuel into the mixing zone;

[0171] c) generating flue gases in the combustion chamber by combusting air and fuel delivered into the mixing zone in step b);

[0172] d) directing the flue gases to said at least one three-way catalytic converter (s);

[0173] e) adjusting the inlet flow (Q_I, Q_{Itot}) of combustion air and the inlet flow (Q_{PA}, Q_{PAtot}) of fuel arriving in the mixing zone in step b) by means of said burner automation, so that the amount of residual oxygen in flue gases (S) will be within the range of 0.01-0.50 preferably in the range of 0.01-0.25% prior to or at the first catalytic zone of said at least one three-way converter,

[0174] (f) delivering supplementary air between the first and the second catalytic zones (**40**, **40**) of the three-way converter (**401**) or between catalytic zones (**40**, **40**) of two successive three-way catalytic converters.

[0175] 17. A flue gas composition defined in example 16 wherein catalytic converter for reducing oxides of nitrogen (NOx) to nitrogen (N_2) and oxygen (O_2) and oxidising hydrocarbons (HC) and carbon monoxide (CO) to carbon dioxide (CO_2) and water (H_2O).

[0176] 18. The flue gas composition defined in example 16 wherein the flue gas mixture comprising O_2, CO, NOx gases which arrives to catalytic zone of said at least one three-way catalytic converter is a homogenous flue gas mixture, produced by a mixer located prior to said first catalytic zone (**40**) in the flue gas conduit or in the heat exchange area.

[0177] 19. The flue gas composition defined in example 16 wherein the flue gas after the both catalytic zones (**40**, **40**) of at least one three-way catalytic converter(s) has NOx concentration in the range of 0-5 ppm, CO within a range of 0-9 ppm and O_2 within a range of 0-0.25%,

[0178] 20. The flue gas composition defined in example 16 wherein flue gas comprises prior to said first catalytic zone (**40**) of at least one three-way catalytic converter O_2 in the range of 0-0.25%, CO under 4000 ppm, NOx under 100 ppm.

[0179] 21. The flue gas composition defined in example 16, wherein the amount of residual oxygen in flue gases arriving to said first catalytic zone (**40**) of at least one three-way catalytic converter is 0-0.25%, measured upstream, downstream or at the catalytic zone (**40**) of said at least one catalytic converter by a lambda-sensor.

[0180] 22. Burner automation (**5**, **6**, **7**) used in a method according to example 1 comprising

[0181] a central processing unit (**5**), including a processor (**52**) and at least one memory element (**51**) which/both of which includes/include a software product/software products (**510**) for controlling the operation of a burner, particularly for adjusting the amount (Q_I, Q_{Itot}, Q_{PA}, Q_{PAtot}) of air and fuel,

[0182] measuring instruments (**6**), such as sensors (**61**, **62**, **63**), for collecting information about a combustion process to be adjusted,

[0183] data transfer elements for receiving measurement data from the measuring instruments (**6**) and communicating the same to the processor (**52**) and software products (**510**) of the central processing unit (**5**), comprising especially the reception of measurement data related to the amount of residual oxygen from a flue gas oxidation/reduction potential-measuring sensor (**63**), such as a lambda sensor, present in flue gases, and the communication of measurement data to the processor (**5**; **52**) and burner control software (**510**) of the central processing unit, as well as for transmitting control instructions, generated by the central processing unit, to actuators (**7**) adjusting the amount of air and fuel (PA) to be delivered, wherein

[0184] the central processing unit (**52**) is adapted to generate, by way of the burner control software (**510**),

[0185] control instructions (**710^5**, **710^6**, **710^7**) related to the amount of the secondary inlet flow (Q_{PAB}) of fuel, whereby the secondary inlet flow (Q_{PAB}) of fuel is adjustable in such a way that the amount (Q_{PAB}) of the secondary inlet flow in the inlet flow (Q_{PAtot}) of fuel is such that the amount of residual oxygen is within the range of 0.01-0.50% preferably within the range of 0.01-0.25% in flue gases prior to the first catalytic zone (**40**) of the at least one three-way catalytic converter (**401**) having at least two catalytic zones (**40**,**40**) or prior to the first catalytic zone (**40**) of at least two three-way catalytic converters (**401**,**401**) having at least one catalytic zones (**40**),

[0186] control instructions (**710^8**) related to the amount of the primary inlet flow (Q_{PAA}) of fuel, which are based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases (**40**),

[0187] control instructions (**710^1**, **710^4**) for the inlet flow of combustion air (I), which are used for adjusting the amount of the inlet flow (Q_I) of combustion air arriving in the windbox (**10**) by way of the combustion air supply conduit (**220**), based on a predetermined amount of residual combustion air oxygen in flue gases, preferably on the amount of 1-2.5% residual oxygen in flue gases, and after being generated by the central processing unit (**5**), the data transfer elements are adapted to communicate control instructions (**710^5**, **710^6**, **710^7**) for the secondary inlet flow (Q_{PAB}) of fuel (PA) to an actuator (**7**) adjusting the amount of the secondary inlet flow, preferably to an actuator-equipped control valve (**7**; **71**), such as a servo motor-operated control valve, adjusting said amount of the secondary inlet flow (Q_{PAB}) in the pipe system (**215**) for the secondary inlet flow,

[0188] control instructions (**710^8**) for the primary inlet flow (Q_{PAA}) of fuel (PA) to an actuator (**7**) adjusting the amount of the primary inlet flow, preferably to an actuator-equipped control valve (**7**; **71**), such as a servo motor-operated control valve, adjusting said amount of the primary inlet flow in the pipe system for the primary inlet flow, and

[0189] control instructions (**710^1**, **710^4**) for the inlet flow of combustion air (I) to an actuator (**7**) adjusting the amount of combustion air, preferably to the inverter of a blower (**7**; **72**) adjusting said amount of combustion air in the combustion air transfer pipe system, and/or to electric motors, such as servo motor-operated valves, adjusting the setting of dampers and valves.

[0190] 23. Burner automation defined in example 22 wherein said burner automation uses Smith predictor for adjusting the amount of the secondary inlet flow.

[0191] 24. The method defined in example 1 wherein said industrial burner has output of at least 3 MWh.

What is claimed is:

1. A method for reducing nitrogen oxide(s) and carbon monoxide from flue gases of an industrial burner, said method comprising the steps of:

a) providing an industrial burner adapted to burn gaseous and/or liquid fuel, and comprising a burner automation containing measuring instruments, and a mixing zone accompanied by a combustion chamber, said burner automation being in communication with measurement instruments of flue gas conduit, said combustion chamber or flue gas conduit being provided with two catalytic zones of at least one three-way catalytic converter (s), which catalytic zones are successive in progressing direction of flue gases;

b) delivering an inlet flow (Q_I, Q_{Itot}) of combustion air and an inlet flow (Q_{PA}, Q_{PAtot}) of fuel into the mixing zone;

c) generating flue gases in the combustion chamber by combusting air and fuel delivered into the mixing zone in step b);

d) measuring the amount of residual oxygen, in flue gases (flue gas oxidation/reduction potential) by a lambda-sensor;

e) directing the flue gases to said at least one three-way catalytic converter(s);

f) adjusting the inlet flow (Q_I, Q_{Itot}) of combustion air and the inlet flow (Q_{PA}, Q_{PAtot}) of fuel arriving in the mixing zone in step b) by means of said burner automation, so that the mean amount of residual oxygen in moles compared to mean amount of carbon monoxide in moles, is 0.5/1 (mole/mole) and O_2 within the range of 0.01-0.50 vol-% preferably in the range of 0.01-0.25 vol % in flue gases prior to or at the first catalytic zone of said at least one three-way converter;

g) delivering supplementary air between the first and the second catalytic zones of the three-way converter or between catalytic zones of two successive three-way catalytic converters, so that concentration in the flue gases after said catalytic zones is within range of 0-9 ppm for NOx and within a range of 0-100 ppm, preferably in the range of 0-40 ppm for CO.

2. The method defined in claim **1** wherein the delivery of supplementary air is based on lambda measurement after the first catalytic zone of at least one three-way catalytic converter (s).

3. The method defined in claim **1** wherein the catalytic three-way converter reduces oxides of nitrogen (NOx) to nitrogen (N_2) and oxygen (O_2) and oxidizes hydrocarbons (HC) and carbon monoxide (CO) to carbon dioxide (CO_2) and water (H_2O).

4. The method defined in claim **1** wherein the flue gas comprising O_2, CO, NOx gases which arrives to the first catalytic zone of said at least one catalytic converter has been homogenized by a mixer located prior to said first catalytic zone in the flue gas conduit or in heat exchange area.

5. The method defined in claim **1** wherein flue gas comprises prior the three-way catalytic converter O_2 in the range of 0.01-0.50 preferably in the range of 0.01-0.25%, CO under 6000 ppm, NOx under 100 ppm and the mean proportion of O_2 to CO is 0.5 mole/1 mole.

6. The method defined in claim **1** wherein the amount of residual CO and NOx is measured from flue gases and measured NOx concentration is within a range of 0-9 ppm and measured CO concentration within a range of 0-100 ppm preferable within the range of 0-40 ppm and wherein the CO sensor that measures the amount of carbon monoxides, as well as the NOx sensor that measures the amount of nitrogen oxides (NOx), are located downstream of the catalytic zones of the at least one three-way catalytic converter(s) in the flowing direction of flue gases (S).

7. The method defined in claim **1**, wherein the amount of residual oxygen in flue gases arriving to said three-way catalytic converter is 0.01-0.25%, measured downstream or at the first catalytic zone of said catalytic converter(s) by a lambda-sensor.

8. The method defined in claim **7**, wherein the amount of residual oxygen in flue gases has been measured by a lambda-sensor located between first and second catalytic zones but before the delivery of supplementary air between said two catalytic zones.

9. The method defined in claim **1** wherein the ratio of fuel (PA) delivered to the combustion head compared to the combustion air (I) delivered into the windbox is adapted to be almost stoichiometric, i.e. within the lambda range of 0.998-1.002.

10. The method defined in claim **1** wherein the method further comprises adjusting the amount of fuel and air arriving in said mixing zone by adapting the ratio of a combustion air flow (Q_I, Q_{Itot}) arriving in a mixing zone to a fuel flow (Q_{PA}, Q_{PAtot}) arriving by way of a fuel supply conduit to be to be such that the amount of residual oxygen is within the range of 0.01-0.25%, in flue gases prior to said first catalytic zone of at least one three-way catalytic converter(s).

11. The method according to claim **10**, wherein the ratio of the combustion air flow (Q_I, Q_{Itot}) arriving in a mixing zone, such as the combustion head, to the fuel flow (Q_{PA}, Q_{PAtot}) arriving in a mixing zone, such as the combustion head, is adapted to oscillate within a certain constantly steady range, preferably by adapting the amount of the combustion air flow (Q_I, Q_{Itot}) to remain constant and by causing the amount of the fuel flow (Q_{PA}, Q_{PAtot}) to oscillate within a certain range so as to approach a desired ratio of the combustion air flow (Q_I, Q_{Itot}) arriving in the mixing zone with respect to the fuel flow (Q_{PA}, Q_{PAtot}) arriving in the mixing zone.

12. The method according to claim **1** wherein

the amount of residual oxygen in flue gases is measured upstream or preferably at the said three-way catalytic converter,

the amount of a combustion air inlet flow (Q_I) arriving at the mixing zone is adjusted by means of burner automation and an actuator present in a combustion air transfer pipe system, such that the adjustment of the combustion air inlet flow (Q_I) is based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases (S),

the fuel inlet flow arriving at the mixing zone is adapted to consist of two separately adjusted portions (Q_{PAA}, Q_{PAB}) of inlet flow proceeding by way of a fuel transfer pipe system into the supply conduit, whereof the first portion (Q_{PAA}) of inlet flow comprises a primary inlet flow, which is adapted to travel in a first section of the transfer pipe system that is in fluid communication with the supply conduit and which makes up 70-100% of the inlet flow, preferably 80-100% of the (total) inlet flow (Q_{PAtot}), and whereof the second portion (Q_{PAB}) of inlet flow comprises a secondary inlet flow, which is adapted to travel in a second section of the transfer pipe system that is likewise in fluid communication with the supply conduit and which makes up 0-30% of the inlet flow, preferably 0-20% of the inlet flow (Q_{PAtot}), whereby

the rate of said primary inlet flow (Q_{PAA}) is adjusted by means of burner automation and an actuator-equipped actuator, such as an electric motor-operated control valve, present in a first transfer pipe system, based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases, and on the primary inlet flow (Q_{PAA}) estimated or calculated on the basis thereof, which combines with the total inlet flow (Q_{PAtot}) of fuel to be delivered to the combustion head by way of the supply conduit, and

the secondary inlet flow (Q_{PAB}) of fuel is adjusted by means of burner automation and actuators, such as an actuator-equipped control valve and an actuator-equipped check valve, present in a second transfer pipe system, based on the amount of residual oxygen measured from flue gases, by means of which the burner automation adjusts the secondary inlet flow (Q_{PAB}) of fuel which combines with the total inlet flow (Q_{totPA}) of fuel arriving at the combustion head by way of the supply conduit,

the ratio of the (total) inlet flow (Q_{totPA}) of fuel to the combustion air flow (Q) arriving in the windbox is maintained such that the amount of residual oxygen is 0.01-0.25%, in flue gases prior to the first catalytic zone of said at least one three-way converter.

13. The method defined in claim **1** wherein the measuring instruments include at least one sensor, such as a lambda sensor, measuring the amount of residual oxygen in flue gases (flue gas oxidation/reduction potential), said method further comprising following steps of:

adjusting an inlet flow (Q_I) of combustion air (I) arriving in the mixing zone said adjustment basing on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases (S), and on the amount of combustion air (I) estimated or calculated on the basis thereof and to be delivered to the mixing zone, and

the fuel inlet flow ($_{totPA}$) is arranged to arrive in the mixing zone by way of the fuel supply conduit so that it consist of two separately regulated portions (Q_{PAA}, Q_{PAB}) of the fuel inlet flow, whereof the first portion (Q_{PAA}) of the inlet flow comprises a primary inlet flow which makes up 70-100% of the inlet flow, preferably 80-100% of the inlet flow, and whereof the second portion (Q_{PAB}) of the inlet flow comprises a secondary inlet flow which makes up 0-30% of the inlet flow, preferably 0-20% of the inlet flow, whereby

the adjustment of said primary inlet flow (Q_{PAA}) of fuel by means of burner automation is based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases, and on the amount of the primary inlet flow (Q_{PAA}) which is estimated or calculated on the basis thereof in the inlet flow ($_{totPA}$) of fuel (PA) to be delivered to the combustion head, and

the adjustment of said secondary inlet flow (Q_{PAB}) of fuel, by means of the burner automation, is based on the amount of residual oxygen measured from flue gases (S), by way of which the burner automation adjusts the amount of the secondary inlet flow (Q_{PAB}) in the inlet flow (Q_{totPA}) of fuel to be delivered to the combustion head such that the, so that the mean amount of residual oxygen in moles compared to mean amount of carbon monoxide in moles is 0.5/1 (mole/mole) wherein and amount of residual oxygen is within the range of 0.01-0.25% in flue gases prior to the first catalytic zone of at least one three-way catalytic converter(s).

14. The method defined in claim **1** wherein said industrial burner has output of at least 3 MWh.

15. The method of claim **14**, wherein the measurement of the amount of residual oxygen of flue gases (S) prior to the first catalytic zone of at least one three-way catalytic converter(s), is performed by a lambda-sensor located after said first catalytic zone and the burner automation adjusts the amount of the secondary inlet flow (Q_{PAB}) in the inlet flow (Q_{totPA}) of fuel to be delivered to the combustion head on the basis of said residual oxygen measurement.

16. The method of claim **15**, wherein additionally the amount of supplementary combustion air supplied between the first and the second catalytic zones of said at least one three-way converter is based on measured oxygen amount which measurement is performed by a lambda-sensor located after said second catalytic zone of said at least one three-way catalytic converter.

17. A flue gas composition, in a space defined by walls of combustion chamber or a flue gas conduit immediately after a three-way catalytic converter of an industrial burner said flue gas composition comprising, CO and NOx gases in which NOx concentration is in the range of 0-9 ppm, CO within a range of 0-40 ppm and wherein said flue gas composition have been made by:

(a) providing an industrial burner adapted to burn gaseous and/or liquid fuel and comprising a burner automation containing measuring instruments, and a mixing zone accompanied by a combustion chamber which is in communication with a flue gas conduit, said combustion chamber or flue gas conduit being provided with at least one three-way catalytic converter having at least two catalytic zones or with at least two three-way catalytic converters which are successive in the progressing direction of flue gases and each converter having at least one catalytic zone, which flue gases comprise O_2, CO, NOx gases and are generated by

b) delivering an inlet flow (Q_I, Q_{Itot}) of combustion air and an inlet flow (Q_{PA}, Q_{PAtot}) of fuel into the mixing zone;

c) generating flue gases in the combustion chamber by combusting air and fuel delivered into the mixing zone in step b);

d) directing the flue gases to said at least one three-way catalytic converter (s);

e) adjusting the inlet flow (Q_I, Q_{Itot}) of combustion air and the inlet flow (Q_{PA}, Q_{PAtot}) of fuel arriving in the mixing zone in step b) by means of said burner automation, so that the amount of residual oxygen in flue gases (S) will be within the range of 0.01-0.50 preferably in the range of 0.01-0.25% prior to or at the first catalytic zone of said at least one three-way converter,

(f) delivering supplementary air between the first and the second catalytic zones of the three-way converter or between catalytic zones of two successive three-way catalytic converters.

18. The flue gas composition defined in claim **17** wherein catalytic converter for reducing oxides of nitrogen (NOx) to nitrogen (N_2) and oxygen (O_2) and oxidising hydrocarbons (HC) and carbon monoxide (CO) to carbon dioxide (CO_2) and water (H_2O).

19. The flue gas composition defined in claim **17** wherein the flue gas mixture comprising O_2, CO, NOx gases which arrives to catalytic zone of said at least one three-way catalytic converter is a homogenous flue gas mixture, produced by a mixer located prior to said first catalytic zone in the flue gas conduit or in the heat exchange area.

20. The flue gas composition defined in claim **17** wherein the flue gas after the both catalytic zones of at least one three-way catalytic converter(s) has NOx concentration in the range of 0-5 ppm, CO within a range of 0-9 ppm and O_2 within a range of 0-0.25%,

21. The flue gas composition defined in claim **17** wherein flue gas comprises prior to said first catalytic zone of at least one three-way catalytic converter O_2 in the range of 0-0. 25%, CO under 4000 ppm, NOx under 100 ppm.

22. The flue gas composition defined in claim **17**, wherein the amount of residual oxygen in flue gases arriving to said first catalytic zone of at least one three-way catalytic converter is 0-0.25%, measured upstream, downstream or at the catalytic zone of said at least one catalytic converter by a lambda-sensor.

23. Burner automation used in a method according to claim **1** comprising

a central processing unit, including a processor and at least one memory element which/both of which includes/include a software product/software products (**510**) for controlling the operation of a burner, particularly for adjusting the amount (Q_I, Q_{Itot}, Q_{PA}, Q_{PAtot}) of air and fuel,

measuring instruments, such as sensors, for collecting information about a combustion process to be adjusted,

data transfer elements for receiving measurement data from the measuring instruments and communicating the same to the processor and software products of the central processing unit, comprising especially the reception of measurement data related to the amount of residual oxygen from a flue gas oxidation/reduction potential-measuring sensor, such as a lambda sensor, present in flue gases, and the communication of measurement data to the processor and burner control software of the central processing unit, as well as for transmitting control instructions, generated by the central processing unit, to actuators adjusting the amount of air and fuel (PA) to be delivered, wherein

the central processing unit is adapted to generate, by way of the burner control software,

control instructions related to the amount of the secondary inlet flow (Q_{PAB}) of fuel, whereby the secondary inlet flow (Q_{PAB}) of fuel is adjustable in such a way that the amount (Q_{PAB}) of the secondary inlet flow in the inlet flow (Q_{PAtot}) of fuel is such that the amount of residual oxygen is within the range of 0.01-0.50% preferably within the range of 0.01-0.25% in flue gases prior to the first catalytic zone of the at least one three-way catalytic converter having at least two catalytic zones or prior to the first catalytic zone of at least two three-way catalytic converters having at least one catalytic zones,

control instructions related to the amount of the primary inlet flow (Q_{PAA}) of fuel, which are based on a predetermined amount of residual oxygen in flue gases (S), preferably on the amount of 1-2.5% residual oxygen in flue gases,

control instructions for the inlet flow of combustion air (I), which are used for adjusting the amount of the inlet flow (Q_I) of combustion air arriving in the windbox by way of the combustion air supply conduit, based on a predetermined amount of residual combustion air oxygen in flue gases, preferably on the amount of 1-2.5% residual oxygen in flue gases, and

after being generated by the central processing unit, the data transfer elements are adapted to communicate control instructions for the secondary inlet flow (Q_{PAB}) of fuel (PA) to an actuator adjusting the amount of the secondary inlet flow, preferably to an actuator-equipped control valve, such as a servo motor-operated control valve, adjusting said amount of the secondary inlet flow (Q_{PAB}) in the pipe system for the secondary inlet flow,

control instructions for the primary inlet flow (Q_{PAA}) of fuel (PA) to an actuator adjusting the amount of the primary inlet flow, preferably to an actuator-equipped control valve, such as a servo motor-operated control valve, adjusting said amount of the primary inlet flow in the pipe system for the primary inlet flow, and

control instructions for the inlet flow of combustion air (I) to an actuator adjusting the amount of combustion air, preferably to the inverter of a blower adjusting said amount of combustion air in the combustion air transfer pipe system, and/or to electric motors, such as servo motor-operated valves, adjusting the setting of dampers and valves.

24. The burner automation defined in claim **23** wherein said burner automation uses Smith predictor for adjusting the amount of the secondary inlet flow.

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