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(54) **A METHOD FOR REDUCING NITROGEN OXIDE EMISSIONS OF A BUBBLING FLUIDIZED BED BOILER**

VERFAHREN ZUR REDUZIERUNG VON STICKOXIDEMISSIONEN EINES KESSELS MIT
BLASENBILDENDEM WIRBELBETT

PROCEDE DESTINE A REDUIRE LES EMISSIONS D'OXYDE D'AZOTE D'UNE CHAUDIERE A LIT
FLUIDISE BOUILLONNANT

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Description

Field of the invention

[0001] The invention relates to a method for reducing nitrogen oxide emissions of a bubbling fluidized bed boiler burning biofuel according to the preamble of the appended claim 1.

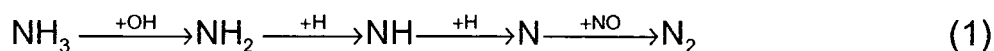
[0002] In this description biofuel refers to solid fuels, wherein the portion of volatile matter in ash-free dry solids is over 60%. This type of fuels are, for example, peat, bark, wood chips, sawdust, waste construction timber, sludge created in process industry, and municipal solid waste.

Background of the invention

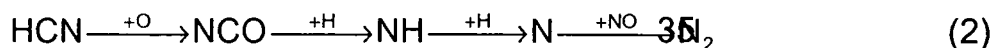
[0003] Bubbling fluidized bed boilers are generally used in energy production, wherein the fuels include biofuels, such as, for example, peat and wood chips. In the lower part of the furnace of a bubbling fluidized bed boiler there is a fluidized bed, which is composed of a fine, incombustible material, typically sand, which fluidizes over a grate forming the bottom of the boiler. The fluidizing of the material is created by feeding fluidizing gas through the grate to the fluidized bed. The fluidizing gas can be composed solely of air, so-called primary air, or it may be a gas mixture formed by primary air and inert gas, for example, flue gas. In a bubbling fluidized bed boiler the flow rate of the fluidizing gas supplied through the grate is set into such that the particles forming the fluidized bed do not escape with air to the upper part of the boiler, but they remain in the lower part of the furnace forming a fluidized bed that is continuously moving and efficiently mixes the fluidized bed material and the fuel supplied to it. The combustion air needed for burning fuel is generally supplied stagewise and in several portions to the furnace of the boiler in such a manner that a part of combustion air, i.e. fluidizing air, is formed by the primary air blown through the grate with the fluidizing gas a part is formed by secondary air supplied above the fluidized bed, and the rest of the combustion air is supplied to the upper part of the furnace of the boiler as so-called tertiary air. The boiler can also be divided into different air zones according to the air supplied to the boiler: the area between the fluidized bed and the secondary air supply is called the primary air zone, and the area between the secondary air supply and the tertiary air supply is called the secondary air zone.

[0004] Fuel is fed by means of so-called carrier air to the bubbling fluidized bed boiler on the fluidized bed. In and on the fluidized bed takes place the drying of fuel particles, the releasing of the volatile matter contained in them (i.e. pyrolysis), and finally the combustion of the remaining carbon residue. Drying and pyrolysis are very fast compared to the total combustion time of fuel particles. The volatile matter released in pyrolysis are mainly methane, CH₄ and carbon monoxide CO, as well as nitrogen oxide emissions causing ammonia NH₃ and hydrogen cyanide HCN. The volatile matter rises upwards and burns when reaching an oxygenous area. In a boiler equipped with staged air supply the combustion of volatile matter primarily is done by secondary air and partly tertiary air, and the combustion of the carbon residue of fuel particle is done by fluidizing, secondary and tertiary air.

[0005] By means of the staged air supply it is possible to reduce the formation of nitrogen oxides. That is, when there is oxygen, NH₃ and HCN react into nitrogen monoxide NO. By staging the air supply, reducing, substoichiometric areas are formed in the furnace of the bubbling fluidized bed boiler. In these areas the NH₃ and HCN formed of fuel are reduced to molecular nitrogen in accordance with the following reaction equations 1 and 2:



and



[0006] In addition, nitrogen oxides are reduced by means of an internal reburning reaction, wherein the hydrocarbon radicals formed in pyrolysis take part in reducing nitrogen oxides. An example of this kind of reaction is shown in reaction equation 3, wherein the hydrocarbon radical is -CHi.



Generally, the reducing areas are formed by adjusting the amount of fluidizing and secondary air. The furnace is maintained substoichiometric in relation to oxygen until the tertiary air supply, in which case the delay time needed for reactions (1) and (2) is maximized and the amount of NH_3 and HCN is minimized before the tertiary air level. The optimum total air coefficient before the tertiary air supply in relation to NO_x emissions is slightly below 1 depending on the combustion temperature. The air required for the burning out of volatile matter and carbon residue is supplied to the furnace as tertiary air. The residue NH_3 and HCN in the flue gases are oxidized after the tertiary air zone into nitrogen oxides.

[0007] With these procedures according to a conventional, staged air supply, the nitrogen oxide emissions can be reduced approximately 30% in comparison to a non-staged air supply. Still problematic are the fine and light fuels, because most of the fuel particles do not end up in the fluidized bed, but they are pulled with the fluidizing gas and secondary air to the upper parts of the furnace. Thus, it is almost impossible for the fuels to create fuel combustion conditions in the furnace that are controlled and favourable to reducing nitrogen oxides.

[0008] It is known from patent FI 108809 (corresponds to WO 01/96783) to reduce the nitrogen oxide emissions formed in the fluidized bed combustion by staging and directing the combustion air supply. The secondary air supplied above the fluidized bed is supplied in a directed manner to the furnace in such a manner that a cyclone is formed, in the middle of which there is a substoichiometric, hydrocarbon-radicals-containing zone and an oxygen-rich zone on the edges. A reburning reaction takes place on the interface of the zones. A purpose of the method is to slow down the combustion of volatile matter on the secondary air level and thus limit the rising of the combustion temperature. However, this method is not efficient enough for getting the nitrogen oxide emissions of the boiler in accordance with the strict emission standards.

[0009] Publication WO 02/090829 also discloses a nitrogen oxide reduction method based on the staging of combustion air. In the method, recirculation gas composed of flue gases is supplied between the supply points of secondary and tertiary airs, in the elevation of the bubbling fluidized bed boiler. Thus, the nitrogen oxides contained by the recirculation gas take part in the final stage of the above-presented reduction reactions (1) and (2) and intensify the reaction of nitrogen compounds formed of the fuel into molecular nitrogen. The problem with this solution is that it causes the amount of flue gases in the boiler to increase, in which case the size of the furnace must be increased, which in turn raises the price of the boiler. In addition, the method is suitable mainly for dry fuels. With wet fuels the amount of heat needed for drying reduces the combustion temperature in the secondary stage too much, thus preventing the creation of conditions favourable for reducing the nitrogen oxides.

[0010] Especially, publication US 6230664 B1 also discloses a nitrogen oxide reduction method based on the staging of combustion air.

Brief description of the invention

[0011] The purpose of the present invention is to provide a method for reducing nitrogen oxide emissions of a bubbling fluidized bed boiler burning biofuel, by means of which the above-mentioned drawbacks can be avoided.

[0012] To attain this purpose, the method according to the invention is primarily characterized in what will be presented in the characterizing part of the independent claim 1.

[0013] The other, dependent claims will present some preferred embodiments of the invention.

[0014] The invention is based on the idea that the nitrogen oxide emissions of a bubbling fluidized bed boiler are reduced by using a staged air supply in such a manner that a part of primary air is supplied in connection with fuel supply, i.e. with the fuel or within the immediate vicinity of the fuel supply point in the same direction as the fuel itself. This part of primary air is in this application referred to as the combustion air of volatile matter. Thus, substantially all the fuel fed to the furnace is forced onto the surface of the fluidized bed for mixing it to the fluidized bed and for drying it quickly due to the effect of the hot fluidized bed material. The pyrolysis following the drying and the combustion of the volatile matter released from the fuel in the pyrolysis also takes place almost immediately after the fuel has mixed with the fluidized bed, because the fuel and the oxygen in the air supplied in connection with it are mixed quickly. Due to the quick mixing of the fuel and the oxygen, most of the volatile matter released from the fuel can be burnt in the upper part of the fluidized bed and on the fluidized bed, before the supply of secondary air. The combustion of volatile matter creates a high temperature, which maximizes the creation of hydrocarbon radicals formed of the fuel and promotes the reduction of the released nitrogen oxides.

[0015] The amount of combustion air of volatile matter supplied in connection with the fuel supply is adjusted into such that the combustion of volatile matter released in pyrolysis from the fuel being burnt takes place in substoichiometric conditions in relation to the volatile matter. The air coefficient SR_v in relation to the volatile matter is thus as high as possible, however, below 1, advantageously between 0.75 to 0.97 and preferably between 0.90 to 0.95. The total air coefficient SR_{tot} on the same level of the furnace varies between 0.50 to 0.80, advantageously being 0.65.

[0016] Secondary air is supplied from the secondary air nozzles and tertiary air is supplied from the tertiary air nozzles placed above the secondary air nozzles. The task of the fluidizing gas supplied to the furnace through its bottom is to maintain the fluidized bed bubbling and its temperature suitable.

[0017] Thus, in the method the combustion air amounts supplied in different stages of the staged combustion are thus adjusted, i.e. the total air coefficient SR_{tot} needed for combustion and further the air coefficient in relation to the volatile matter SR_v . This is illustrated later in tables 1 and 2 of this description. Feeding the fuel with air to the fluidized bed in such a manner that substantially all the fuel particles are forced there enables controlling the combustion substantially better than at present. Further, the amount of unburnt fuel can be minimized, because the delay time of fuel in the furnace is longer than in the solutions according to prior art.

[0018] Thus, in the method, it is not the amount of air supplied to the furnace nor the total air coefficient that is affected, but how the air distribution is performed in order to have the air coefficient in relation to the volatile matter of the fuel as high as possible as low in the furnace as possible and yet as long as possible before the secondary air nozzles.

[0019] Several advantages are reached by means of the invention. Because combustion air is supplied together with the fuel or in the immediate vicinity of the fuel feeding point in the same direction as the fuel itself, the finely divided fuels, such as, for example peat, are forced on the surface of the fluidized bed, in which case they come into immediate contact with the hot fluidized bed material and do not escape to the upper parts of the furnace. Thus, the fuel is made to dry and inflame quickly in its entirety and the volatile matter released from it are burnt as low in the furnace as possible. Most of the volatile matter can be burnt before the actual secondary air level. The high temperature created in the combustion of volatile matter creates hydrocarbon radicals, which breaks down the formed nitrogen monoxide into molecular nitrogen before the secondary air zone.

[0020] Because the fine particles are forced by means of air on the surface of the fluidized bed, their delay time in the furnace before the secondary air supply is longer than in the solutions of prior art. Thus, the volatile matter in the fuel have time to burn almost completely before they travel upwards in the furnace.

[0021] The fact that the fuel particles are forced by means of air to the fluidized bed also reduces the fouling of heat exchange surfaces of the furnace. That is, the fuel particles escaping from the fuel supply and burning in the upper parts of the furnace raise the temperature of the fuel gases before they reach the heat surfaces and increase the fouling caused by ash melting. Fouling of the heat exchange surfaces diminishes the efficiency of the boiler and causes economical losses through boiler shutdowns required by the possible cleaning. By means of the invention fouling is minimized and through that, economic advantage is gained.

[0022] By means of the invention it is also possible to build the furnace of the boiler smaller in size and thus decrease the investment expenses of the boiler, because the combustion reactions take place lower in the boiler, in which case the heat transfer in the lower part of the boiler is more efficient.

Brief description of the drawings

[0023] In the following, the invention will be described in more detail with reference to the appended drawings, in which

Fig. 1 shows schematically a furnace of a bubbling fluidized bed boiler in a side view,

Fig. 2 shows schematically a furnace of a bubbling fluidized bed boiler in a front view,

Fig. 3a shows fuel supply means seen from the inside of the furnace,

Fig. 3b shows fuel supply means according to a second embodiment seen from the inside of the furnace,

Fig. 3c shows fuel supply means according to a third embodiment seen from the inside of the furnace,

Fig. 4 shows the amount of pyrolysis gas in a furnace, and

Fig. 5 shows temperature distribution in a furnace above the surface of the bed.

Detailed description of the invention

[0024] Fig. 1 shows a side view of a furnace of a bubbling fluidized bed boiler 1. There is a fluidized bed 2 composed of bed material on the bottom of the furnace. Fluidizing gas is supplied to the furnace 1 through nozzles 4 arranged on its bottom 3, which gas fluidizes the bed material. The fluidizing gas can be solely air, or it may be a mixture of air and recirculating gas. The fuel is supplied to the fluidized bed 2 from fuel supply means 5 arranged above the surface of the fluidized bed and placed substantially on a mutually same level. In the figure there are three fuel feeding means, but their number may vary depending on the size of the furnace or other parameters of the boiler. Fuel feeding means can also be arranged on the opposite side wall (not shown) of the furnace substantially on the same level with the fuel feeding means arranged on the side wall, as shown in the figure. They can also be placed on the front and/or back walls of the

furnace. The fuel is fed to the fluidized bed by means of air. The amount of air used in connection with fuel feeding is so large, that it prevents fuel particles from escaping to the upper parts of the furnace by directing the fuel substantially on the surface of the fluidized bed. The additional air, combustion air of the volatile matter supplied in connection with air supply is a part of primary air. Secondary air is supplied from secondary air nozzles 6 located above the fuel feeding means to above the fluidized bed 2. Tertiary air is supplied to the furnace above the secondary air nozzles 6 via tertiary air nozzles 7 arranged in the upper part of the furnace.

[0025] The amount of air supplied to the furnace does not therefore increase in comparison to a conventional solution, but it is distributed in a different manner. The amount of primary air supplied as fluidizing gas or as a part of it and the amount of tertiary air remain substantially equal to conventional staged combustion. However, in connection with fuel feeding, separate combustion air of volatile matter is supplied to the furnace, which air correspondingly decreases the amount of secondary air.

[0026] Fig. 2 shows a front view of a furnace 1 of a bubbling fluidized bed boiler. Fuel is fed from a fuel supply means 5 to the fluidized bed 2. Fuel feeding takes place by means of carrier air and the combustion air of volatile matter, in which case the fuel-air-mixture 8 is forced all the way to the surface 2a of the fluidized bed 2. Finely divided fuel supplied to the fluidized bed dries immediately when coming into contact with hot bed material and pyrolyzes substantially entirely. In pyrolysis the volatile matter released from the fuel burn on the surface 2a of the fluidized bed 2 and above the surface 2a of the fluidized bed by means of primary air forming a first, reducing primary air zone 9, which extends from the upper part of the fluidized bed to the secondary air nozzles 6. The combustion of volatile matter takes place in the primary air zone 9 in substoichiometric conditions in relation to the air coefficient SR_v of volatile matter. Thus, also the total air coefficient SR_{tot} is naturally below 1. When the air coefficient SR_v in relation to volatile matter is as large as possible, but still a little below 1, the volatile matter burns quickly and forms a high local temperature, and it forms a maximum amount of hydrocarbon radicals, which are needed in order to reduce nitrogen oxides formed from the fuel. The reducing secondary air zone 10 extends from the secondary air nozzles all the way to the tertiary air nozzles arranged over them.

[0027] Reducing the nitrogen oxides formed from fuel into molecular nitrogen is thus performed in two stages. In the first reducing stage, i.e. in the primary air zone 9, most of the volatile matter released from the fuel and a part of the carbon residue is burnt. This takes place in relation to both the total air coefficient SR_{tot} and the air coefficient SR_v of the volatile matter of the fuel in substoichiometric conditions, which results in a large amount of hydrocarbon radicals. The primary air required in this stage is brought to the furnace in connection with fuel supply and at least as a part of the fluidizing gas. 75 to 95%, preferably 90% of the air needed for combustion of pyrolysis gases is supplied as primary air. In the second reducing stage, i.e. the secondary air zone 10 following the first stage, combustion air is supplied to the furnace from secondary air nozzles 6 arranged within a distance from the surface of the fluidized bed in such a manner that the substoichiometric conditions remain, i.e. the total air coefficient SR_{tot} is still below 1. The air coefficient SR_v of volatile matter of the fuel rises in this zone above 1. Feeding of primary air in the manner described above in two stages, as fluidizing air and as combustion air of volatile matter has the effect that the temperatures in the lower parts of the furnace are higher than in known boilers equipped with staged air distribution. By means of the method, the fuel is inflamed quickly and most of the volatile matter can be burnt before the actual secondary air level.

[0028] In figure 2 there are three secondary and tertiary air nozzles 6 and 7 side by side on the front wall of the furnace. Their number and placement may vary depending on the size of the boiler. The air nozzles can also be placed on the side walls of the boiler.

[0029] The following tables 1 and 2 show two examples of applying the method in a bubbling fluidized bed boiler, whose firing rate is 300 MW. The examples show stagewise both the air distribution in a bubbling fluidized bed boiler according to prior art and the air distribution in the same boiler in accordance with the method when the fuel and boiler load remain the same. The air amount (kg/s) supplied to the boiler in each stage, the total air coefficient SR_{tot} of the stage in question and the air coefficient in relation to the volatile matter SR_v are shown. In the example of table 1 the fuel is peat and in the example of table 2 the fuel is wood. When comparing the air amounts it is to be taken into account that in air distribution according to prior art air is supplied to the primary air zone only as fluidizing air along with the fluidizing gas and the carrier air amount used in fuel supply is a small part of the total amount of combustion air. In the method the combustion air of volatile matter supplied in connection with fuel supply and the fluidizing air supplied together with the fluidizing gas form the amount of primary air supplied to the furnace. The small amounts of cooling air of the start-up burners have not been taken into account in dimensioning the combustion air of volatile matter, because they do not penetrate to the furnace and therefore they do not take part in the combustion in the primary air zone.

Table 1.

Fuel peat, full power of the boiler.						
	Air distribution according to prior art			Air distribution according to the invention		
	Air (kg/s)	SR _{tot}	SR _v	Air (kg/s)	SR _{tot}	SR _v
Fluidizing air	41	0,39	0,66	41	0,39	0,66
Carrier air	6	0,44	0,76	6	0,44	0,76
Combustion air of volatile matter	0	0,44	0,76	12	0,56	0,95
Start-up burner cooling	3,5	0,48	0,81	3,5	0,59	1,00
Secondary air	44	0,89	1,52	32	0,89	1,52
Load carrying burner cooling	4	0,93	1,58	4	0,93	1,58
Tertiary air	23	1,14	1,95	23	1,14	1,95
Total	121,5	1,145	1,952	121,5	1,145	1,952

[0030] The percentage of the volatile matter of the dry fuel flow is approximately 70 mass-%, coke approximately 24.5 mass-% and ash approximately 5.5 mass-%. The moisture content of the fuel is 46 mass-%.

Table 2.

Fuel wood, full power of the boiler.						
	Air distribution according to prior art			Air distribution according to the invention		
	Air (kg/s)	SR _{tot}	SR _v	Air (kg/s)	SR _{tot}	SR _v
Fluidizing air	38	0,36	0,48	38	0,36	0,48
Carrier air	6	0,42	0,55	6	0,42	0,55
Combustion air of volatile matter	0	0,42	0,55	31,5	0,72	0,95
Start-up burner cooling	3,5	0,45	0,60	3,5	0,75	0,99
Secondary air	46,5	0,89	1,18	15	0,89	1,18
Load carrying burner cooling	4	0,93	1,23	4	0,93	1,23
Tertiary air	23	1,15	1,52	23	1,15	1,52
Total	121	1,147	1,520	121	1,147	1,520

[0031] The percentage of the volatile matter of the dry fuel flow is approximately 85 mass-%, coke approximately 13 mass-% and ash approximately 2 mass-%. The moisture content of the fuel is 46 mass-%.

[0032] As can be seen in the examples, the new air distribution according to the method has an effect on the amounts of additional air and secondary air supplied in connection with fuel supply. The other, fluidizing air and tertiary air supplied together with the fluidizing gas, as well as the small air amounts used in cooling start-up burners and load carrying burners remain the same as in air distribution according to prior art. The amount of air supplied together with the fuel is significantly larger than the amount of carrier air used for fuel supply in prior art. The amount of air supplied with the fuel varies depending on the fuel, because different fuels contain different amounts of volatile matter and the purpose is to burn them in substoichiometric conditions before the supply of secondary air.

[0033] The additional air fed in connection with fuel supply, i.e. the combustion air of volatile matter, which is a part of primary air, can be supplied either with the fuel, mixed into the carrier air of the fuel, or parallelly with the fuel supply taking place by the carrier air. Figure 3a shows a fuel supply means 5, i.e. a fuel feeding opening 5a seen from the inside of the furnace, wherein the fuel and the combustion air supplied with it are mixed right before they are fed to the furnace together. The feeding opening 5a is rectangular, which is the most advantageous form for a feeding opening, but otherwise shaped feeding openings may also be applied. In the fuel feeding means 5 shown in figure 3b the fuel and combustion air are fed parallel to the furnace. The fuel is fed to the furnace by means of carrier air from the fuel feeding opening 5a, which is on three sides surrounded by a uniform air channel 11 for supplying combustion air of volatile matter. The air channel 11 is a uniform channel and it surrounds the fuel feeding opening from its three sides in such a manner that

there is no air supply from below the feeding opening 5a. Thus, when being fed, the fuel is forced in an "air tunnel" formed by combustion air of volatile matter, which directs the fuel, forces it onto the surface 2a of the fluidized bed 2 and thus prevents the fuel particles from escaping to the upper parts of the furnace. Thus, the momentum of combustion air is so high that the fuel cannot escape. In the embodiments of figure 3c, the air channels 11a, 11 b and 11c are

separate air channels in relation to the fuel feeding opening 5a, which channels are placed within a small distance from the fuel feeding opening 5a, on its three sides. The air channels 11 a to 11c are also placed in such a manner that there is no air channel under the fuel feeding opening 5a. The design of the air channel and the placement of the air channels 11 a to 11c in relation to the fuel feeding opening help in directing the fuel particles to be directed to the fluidized bed.

[0034] The method is illustrated in figures 4 and 5 by means of graphs, which are formed by modelling a bubbling fluidized bed boiler with a fuel power of 300 MW with a full load, wherein the fuel has been a mixture of peat (70%) and wood (30%). Each graph shows two curves: curves for both the air distribution according to prior art and the air distribution according to the method. These different air distributions are explained in connection with tables 1 and 2.

[0035] Figure 4 shows the portion of pyrolysis gas in a furnace above the surface of the bed, wherein the portion of pyrolysis gases formed as a result of air distribution according to prior art is illustrated by dashed lines and the portion of pyrolysis gases reached by means of the method is illustrated with a solid line. The graphs show that by means of the method the releasing and combustion of pyrolysis gas mostly take place before the secondary air supply. In a bubbling fluidized bed boiler equipped with air distribution according to prior art the releasing of pyrolysis gas significantly takes place before the secondary air level, but because of lack of oxygen hardly any combustion takes place. Because of the escaping fuel particles, the releasing of pyrolysis gases takes place even on secondary and tertiary air levels.

[0036] Figure 5 shows the temperature distribution above the bed of a furnace. The temperature distribution according to prior art is shown by dashed lines and the temperature distributions reached by means of the method are shown by a solid line. It can be seen from the graphs that by means of the method the temperature of the furnace is higher in the primary air zone than in a bubbling fluidized bed boiler equipped with air distribution according to prior art. The temperature remains higher almost to the tertiary level, after which it decreases to lower than in prior art, because there is no more combustible matter left.

[0037] The invention is not intended to be limited to the embodiments presented as examples above, but the invention is intended to be applied widely within the scope of the appended claims.

Claims

1. A method for reducing nitrogen oxide emissions of a bubbling fluidized bed boiler burning biofuel, the method comprising:

- supplying at least primary air to a fluidized bed (2) arranged in a lower part of a furnace (1) of the fluidized bed boiler for fluidizing bed material forming the fluidized bed (2) in the furnace,
- feeding fuel comprising volatile matter to the fluidized bed (2), which dries when coming into contact with hot bed material and pyrolyzes into pyrolysis gas comprising volatile matter of the fuel, which pyrolysis gas rises upwards in the furnace and burns there,
- burning at least a part of carbon residue from the pyrolysis in the fluidized bed (2) with the primary air,
- supplying secondary air above the fluidized bed from secondary air nozzles, and
- supplying tertiary air above the secondary air nozzles from tertiary air nozzles,

characterized by:

- supplying, for burning at least a part of the pyrolysis gas, combustion air of volatile matter to the furnace (1) such that the fuel is forced substantially on the surface of the fluidized bed (2) and the fuel comprising volatile matter is pyrolyzed substantially entirely into the pyrolysis gas, wherein the combustion air of volatile matter is supplied to the furnace (1) together with the fuel or parallelly with the fuel,
- burning at least a part of the pyrolysis gas in a primary air zone (9) located between an upper part of the fluidized bed and the secondary air nozzles (6) where the air coefficient in relation to the volatile matter in the pyrolysis gas is in the substoichiometric area, wherein the air coefficient in relation to the volatile matter is 0.75 to 0.97 and the total air coefficient in the primary air zone is 0.5 to 0.8, and
- burning the pyrolysis gas in a substoichiometric secondary air zone (10) located between the secondary air nozzles and the tertiary air nozzles (7), wherein the air coefficient in relation to the volatile matter is more than 1 and the total air coefficient is 0.7 to 0.95.

2. The method according to claim 1, **characterized in that** the combustion air of volatile matter is supplied to the

furnace (1) such that at least a part of the pyrolysis gas is burnt before secondary air is supplied to the furnace.

3. The method according to claim 1, **characterized in that** said part of the pyrolysis gas is burnt by the primary air supplied to the furnace.
4. The method according to claim 1, **characterized in that** fuel is forced onto the surface of the fluidized bed by the momentum of the combustion air of volatile matter supplied.
5. The method according to claim 1, **characterized in that** the primary air zone (9) comprises a great deal of hydrocarbon radicals which reduce nitrogen oxides.
6. The method according to claim 1, **characterized in that** the combustion air of volatile matter is supplied to the furnace (1) such that the air coefficient (SR_v) in relation to the volatile matter is 0.90 to 0.95.
7. The method according to claim 6, **characterized in that** the total air coefficient (SR_{tot}) is 0.65.
8. The method according to claim 1, **characterized in that** the secondary air zone is nitrogen-oxides-reducing in which secondary air zone the total air coefficient (SR_{tot}) is 0.85 to 0.9.
9. The method according to claim 1, **characterized in that** the combustion air of volatile matter is supplied to the furnace (1) around a fuel feeding opening (5a).
10. The method according to claim 1, **characterized by** supplying recirculating gas to the fluidized bed (2) in order to fluidize the bed material forming the fluidized bed (2) in the furnace (1).

Patentansprüche

1. Verfahren zur Verringerung der Stickoxidemissionen eines sprudelnden Wirbelschichtkessels, der mit Biobrennstoff befeuert wird, wobei das Verfahren Folgendes umfasst:

- Zuführen mindestens primärer Luft in eine Wirbelschicht (2), die in einem unteren Bereich einer Feuerungsanlage (1) des Wirbelschichtkessels angeordnet ist, welcher für das Wirbelschichtmaterial bestimmt ist, das die Wirbelschicht (2) in der Feuerungsanlage bildet,
- Einspeisen von Brennstoff, der flüchtige Stoffe umfasst, in die Wirbelschicht (2), wobei dieser trocknet, wenn er mit dem heißen Schichtmaterial in Kontakt kommt, und eine Pyrolyse zu einem Pyrolysegas erfährt, das flüchtige Stoffe des Brennstoffs umfasst, wobei das Pyrolysegas nach oben in die Feuerungsanlage aufsteigt und dort verbrennt,
- Verbrennen mindestens eines Teils des Kohlenstoffrückstands aus der Pyrolyse in der Wirbelschicht (2) mit der primären Luft,
- Zuführen von sekundärer Luft oberhalb der Wirbelschicht, ausgehend von Sekundärluftdüsen, und
- Zuführen von tertiärer Luft oberhalb der Sekundärluftdüsen, ausgehend von Tertiärluftdüsen,

gekennzeichnet durch:

- Zuführen von Luft zum Verbrennen flüchtiger Stoffe in die Feuerungsanlage (1), um mindestens einen Teil des Pyrolysegases zu derart zu verbrennen, dass der Brennstoff zwangsläufig im Wesentlichen an die Oberfläche der Wirbelschicht (2) gelangt und der Brennstoff, welcher flüchtige Stoffe umfasst, im Wesentlichen vollständig zu Pyrolysegas pyrolysiert wird, wobei die Luft zum Verbrennen flüchtiger Stoffe zusammen mit dem Brennstoff oder parallel zu dem Brennstoff der Feuerungsanlage (1) zugeführt wird,
- Verbrennen mindestens eines Teils des Pyrolysegases in einem Primärluftbereich (9), der sich zwischen einem oberen Abschnitt der Wirbelschicht und den Sekundärluftdüsen (6) befindet, wobei die Luftzahl im Verhältnis zu den flüchtigen Stoffen im Pyrolysegas im unterstöchiometrischen Bereich liegt, wobei die Luftzahl im Verhältnis zu den flüchtigen Stoffen 0,75 bis 0,97 beträgt und die Luftzahl im Primärluftbereich insgesamt 0,5 bis 0,8 beträgt, und
- Verbrennen des Pyrolysegases in einem unterstöchiometrischen Sekundärluftbereich (10), der sich zwischen den Sekundärluftdüsen und den Tertiärluftdüsen (7) befindet, wobei die Luftzahl im Verhältnis zu den flüchtigen Stoffen mehr als 1 beträgt und die Gesamtluftzahl 0,7 bis 0,95 beträgt.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Luft zum Verbrennen flüchtiger Stoffe der Feuerungsanlage (1) derart zugeführt wird, dass mindestens ein Teil des Pyrolysegases verbrannt wird, bevor der Feuerungsanlage Sekundärluft zugeführt wird.
3. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** der Teil des Pyrolysegases mittels der Primärluft verbrannt wird, welcher der Feuerungsanlage zugeführt wird.
4. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** der Brennstoff durch den Impuls der zugeführten Luft zum Verbrennen flüchtiger Stoffe zwangsläufig an die Oberfläche der Wirbelschicht gelangt.
5. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** der Primärluftbereich (9) viele Kohlenwasserstoffradikale umfasst, die Stickoxide reduzieren.
6. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Luft zum Verbrennen flüchtiger Stoffe der Feuerungsanlage (1) derart zugeführt wird, dass die Luftzahl (SR_v) im Verhältnis zu den flüchtigen Stoffen 0,90 bis 0,95 beträgt.
7. Verfahren nach Anspruch 6, **dadurch gekennzeichnet, dass** die Gesamtluftzahl (SR_{tot}) 0,65 beträgt.
8. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** der Sekundärluftbereich auf Stickoxide reduzierend wirkt, wobei die Gesamtluftzahl (SR_{tot}) im Sekundärluftbereich 0,85 bis 0,9 beträgt.
9. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Luft zum Verbrennen flüchtiger Stoffe der Feuerungsanlage (1) rundum eine Brennstoff-Einspeiseöffnung (5a) zugeführt wird,.
10. Verfahren nach Anspruch 1, **gekennzeichnet durch** das Zuführen von zurückgeführtem Gas in die Wirbelschicht (2), um das Schichtmaterial, welches die Wirbelschicht (2) in der Feuerungsanlage (1) bildet, in einen fließfähigen Zustand zu versetzen.

Revendications

1. Procédé pour la réduction des émissions d'oxydes d'azote d'un biocombustible de combustion d'une chaudière à lit fluidisé bouillonnant, le procédé comprenant le fait de :

- acheminer au moins de l'air primaire à un lit fluidisé (2) disposé dans une partie inférieure d'un foyer (1) de la chaudière à lit fluidisé pour fluidiser la matière du lit formant le lit fluidisé (2) dans le foyer ;
- alimenter en combustible comprenant des produits volatils le lit fluidisé (2), qui sèche lorsqu'il entre en contact avec la matière chaude du lit et qui subit une pyrolyse pour se transformer en gaz de pyrolyse comprenant les produits volatils du combustible, ledit gaz de pyrolyse s'élevant en direction ascendante dans le four et y brûlant ;
- brûler au moins une partie du résidu carboné de la pyrolyse dans le lit fluidisé (2) avec l'air primaire ;
- acheminer de l'air secondaire au-dessus du lit fluidisé à partir de buses pour l'air secondaire ; et
- acheminer de l'air tertiaire au-dessus des buses pour l'air secondaire à partir de buses pour l'air tertiaire ;

caractérisé par le fait de :

- acheminer, pour brûler au moins une partie du gaz de pyrolyse, de l'air de combustion constitué par des produits volatils au foyer (1) d'une manière telle que le combustible est forcé essentiellement sur la surface du lit fluidisé (2) et le combustible comprenant des produits volatils est soumis à une pyrolyse de manière essentiellement complète pour obtenir le gaz de pyrolyse, l'air de combustion constitué par des produits volatils étant acheminé au foyer (1) de manière conjointe avec le combustible ou parallèlement au combustible ;
- brûler au moins une partie du gaz de pyrolyse dans une zone pour l'air primaire (9) située entre une partie supérieure du lit fluidisé et les buses (6) pour l'air secondaire, le coefficient de l'air par rapport aux produits volatils dans le gaz de pyrolyse se situant dans la plage sous-stoechiométrique, le coefficient de l'air par rapport aux produits volatils s'élevant de 0,75 à 0,97 et le coefficient total de l'air dans la zone pour l'air primaire s'élevant de 0,5 à 0,8 ; et
- brûler le gaz de pyrolyse dans une zone sous-stoechiométrique pour l'air secondaire (10) située entre les buses pour l'air secondaire et les buses (7) pour l'air tertiaire, le coefficient de l'air par rapport aux produits

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volatils étant supérieur à 1 et le coefficient total de l'air s'élevant de 0,7 à 0,95.

2. Procédé selon la revendication 1, **caractérisé en ce que** l'air pour la combustion des produits volatils est acheminé au foyer (1) d'une manière telle qu'au moins une partie du gaz de pyrolyse est brûlée avant d'acheminer l'air secondaire au foyer.
3. Procédé selon la revendication 1, **caractérisé en ce que** ladite partie du gaz de pyrolyse est brûlée par l'air primaire acheminé au foyer.
4. Procédé selon la revendication 1, **caractérisé en ce que** du combustible est forcé sur la surface du lit fluidisé par la quantité de mouvement de l'air de combustion acheminé, constitué par les produits volatils.
5. Procédé selon la revendication 1, **caractérisé en ce que** la zone pour l'air primaire (9) comprend une grande quantité de radicaux d'hydrocarbures qui réduisent les oxydes d'azote.
6. Procédé selon la revendication 1, **caractérisé en ce que** l'air pour la combustion des produits volatils est acheminé au foyer (1) d'une manière telle que le coefficient de l'air (SR_v) par rapport aux produits volatils s'élève de 0,90 à 0,95.
7. Procédé selon la revendication 6, **caractérisé en ce que** le coefficient total de l'air (SR_{tot}) s'élève à 0,65.
8. Procédé selon la revendication 1, **caractérisé en ce que** la zone pour l'air secondaire est une zone de réduction des oxydes d'azote dans laquelle le coefficient total de l'air (SR_{tot}) s'élève de 0,85 à 0,9.
9. Procédé selon la revendication 1, **caractérisé en ce que** l'air pour la combustion des produits volatils est acheminé au foyer (1) autour d'une ouverture d'alimentation de combustible (5a).
10. Procédé selon la revendication 1, **caractérisé par** le fait d'acheminer un gaz de recirculation au lit fluidisé (2) dans le but de fluidiser la matière du lit formant le lit fluidisé (2) dans le foyer.

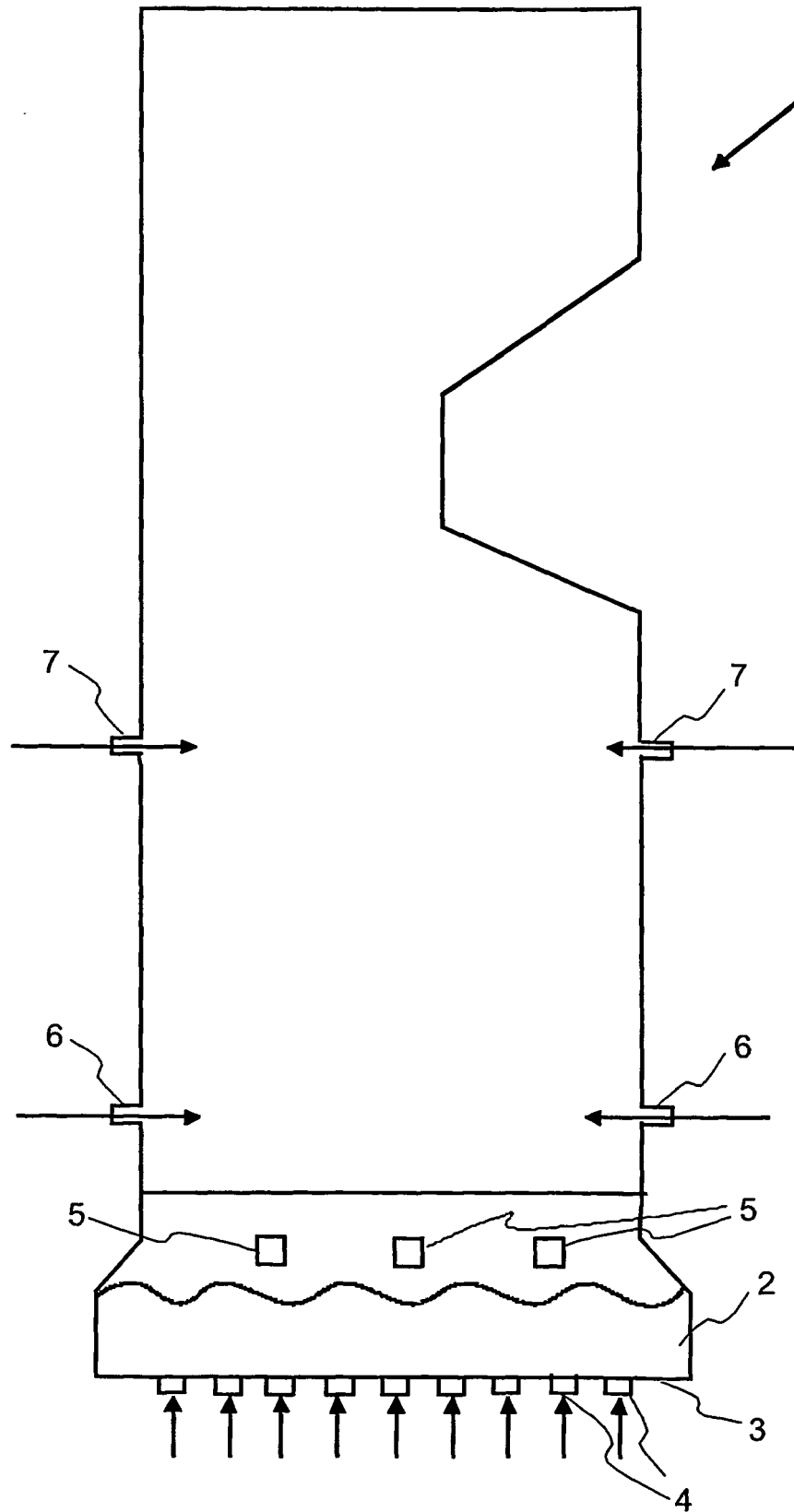


Fig. 1

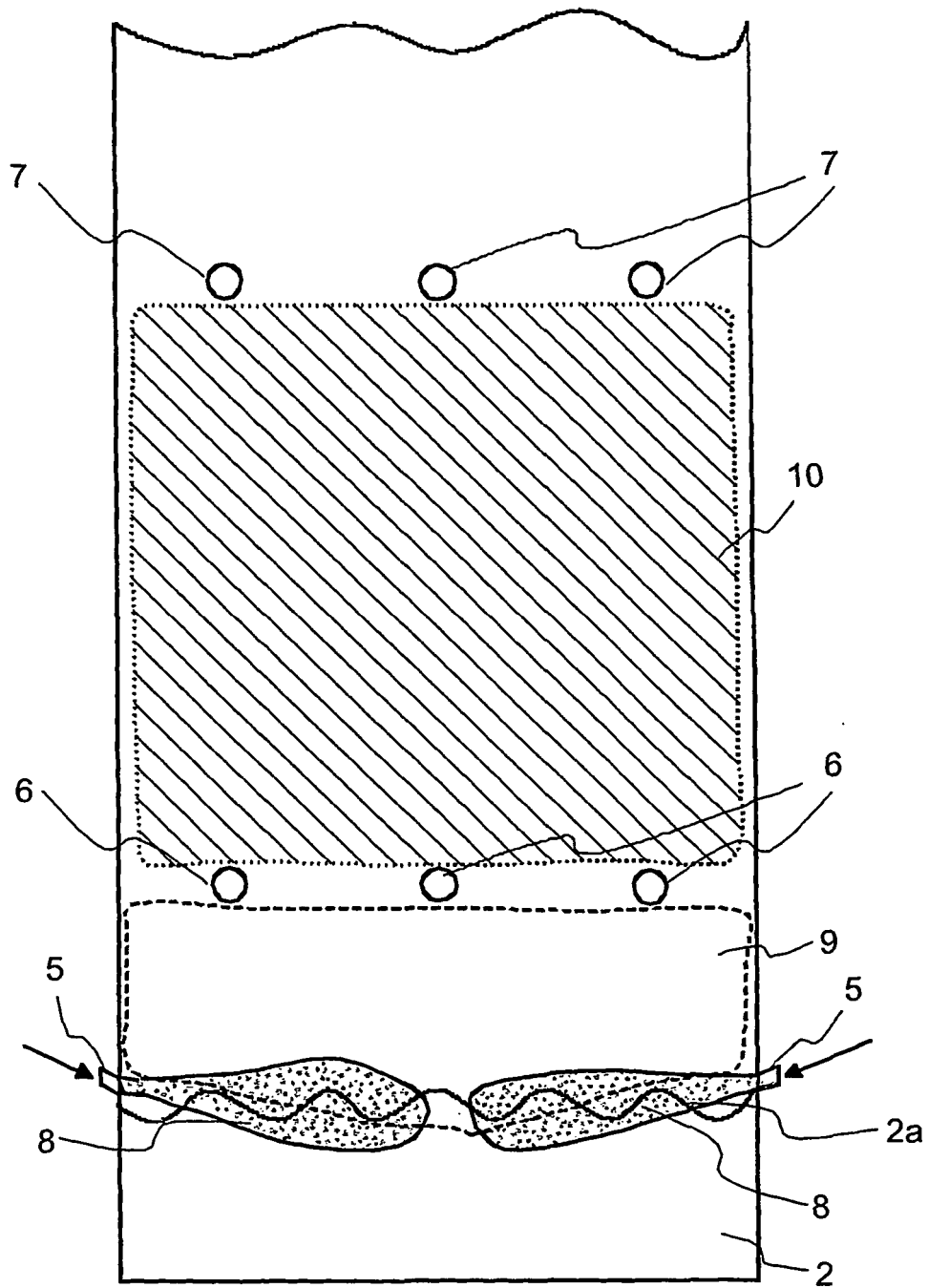


Fig. 2

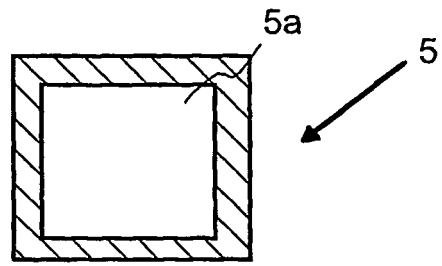


Fig. 3a

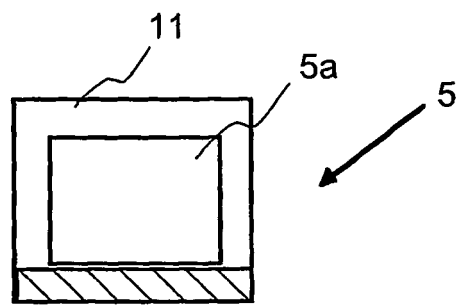


Fig. 3b

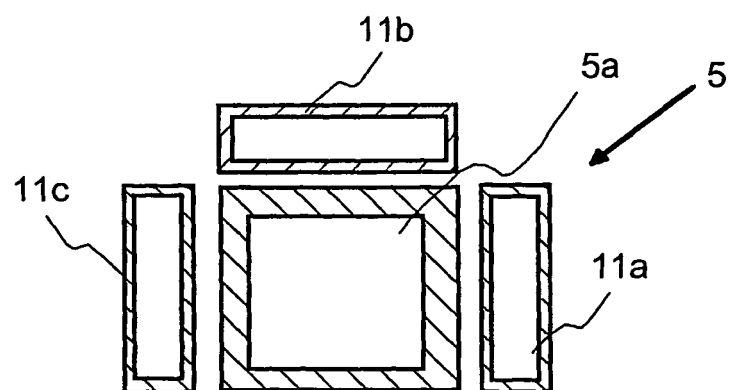


Fig. 3c

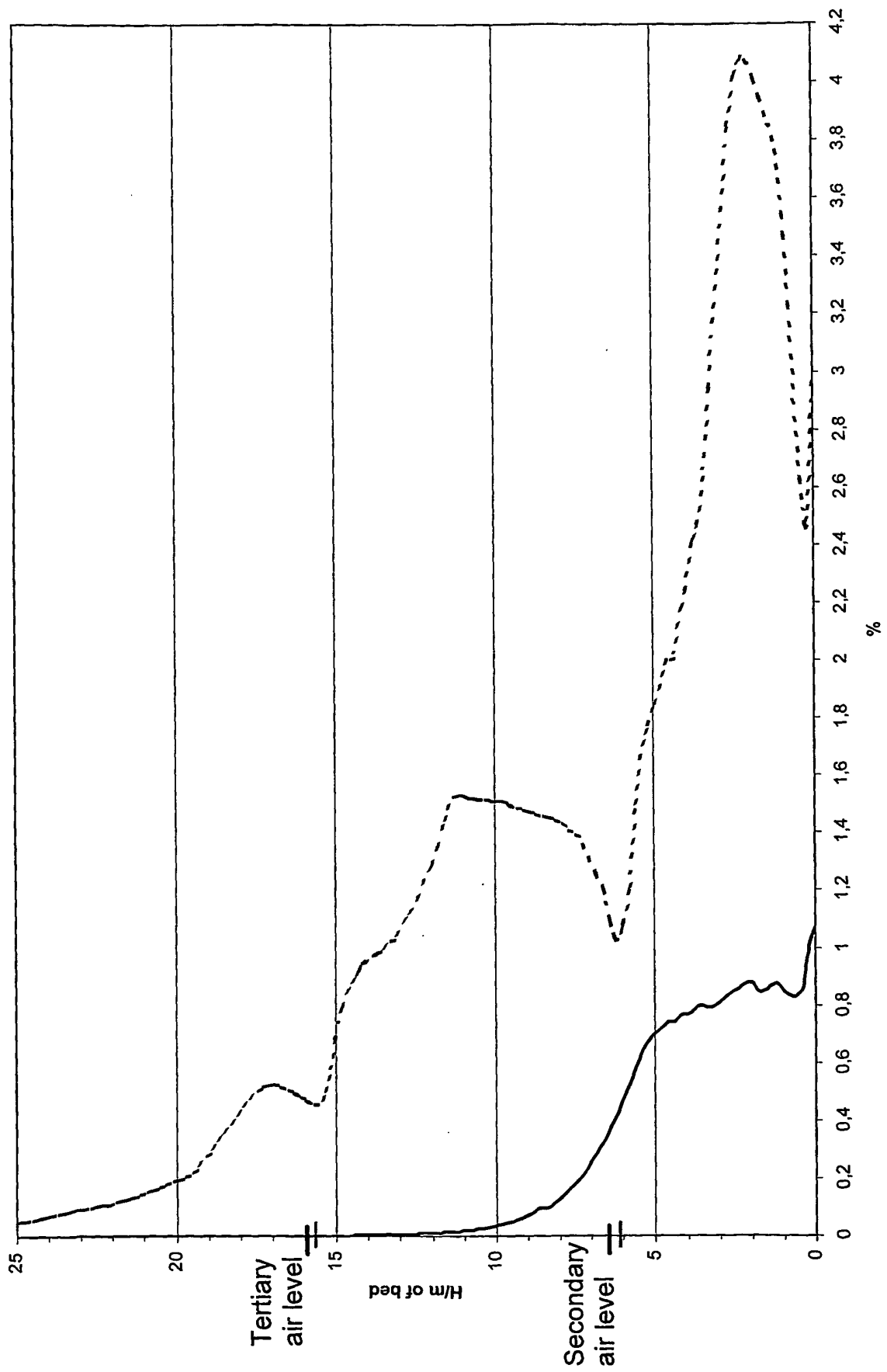


Fig. 4



Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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