A plant for purifying the flue gases from a furnace, in particular from a rotary cement kiln, has at least one selective reduction catalyst for reducing nitrogen oxides present in the flue gas, optionally introduction of a reducing agent and a dust filter or precipitation system. The dust precipitation system is formed by at least one first and one second filter apparatus. The reduction catalyst is arranged between the first and second filter apparatuses.
FLUE GAS PURIFICATION PLANT

[0001] The invention relates to a plant for purifying the flue gases from a furnace, including at least one selective reduction catalyst for reducing nitrogen oxides present in the flue gas, and/or at least one catalyst for reducing carbon monoxide from, particularly odor-forming, hydrocarbons or for removing ammonia, as well as a dust separation means, and a method for purifying the flue gases from a furnace by the selective catalytic reduction of nitrogen oxides by a reducing agent and a reduction catalyst as well as by dust separation.

[0002] The removal of nitrogen oxides, or denitrification, is usually carried out by reductive methods. In this respect, distinction is made between the selective non-catalytic reduction (SNCR) and the selective catalytic reduction (SCR). These methods are known to degrade the nitrogen or nitric oxides (NOx) contained in flue gases, i.e. nitrogen monoxide and nitrogen dioxide, by the addition of a reducing agent—in general, ammonia is used as a reducing agent—to elementary nitrogen and water, which will subsequently leave the combustion plant via the flue gas stack as environmentally harmless substances.

[0003] The selective non-catalytic reduction is usually carried out at temperatures between 900° C. and 1100° C., with the reducing agent being directly fed into the furnace.

[0004] The selective catalytic reduction can be performed at distinctly lower temperatures, since the catalyst significantly reduces the activation energies required for the reducing reactions. This method, moreover, allows for a decrease of the reducing agent charge as compared to SNCR denitrification, where the reducing agent is used in a hyperstoichiometric amount, since practically no side reactions will occur.

[0005] The selective catalytic reduction differentiates between high-dust configurations and low-dust configurations. With high-dust configurations, the denitrification of the flue gases takes place prior to dusting, which is why the catalyst is subject to elevated wear. This will, as a rule, result in reduced dwell times of the catalyst, and call for expensive measures, e.g., the use of special catalysts with suitable geometries of the flue gas channels extending through the catalyst bed as is, for instance, described in DE 296 23 503 U1 or DE 196 35 383 A1, or the use of catalysts that are capable of withstanding higher mechanical stresses caused, for instance, by the periodic shaking-off of the dust loads from the catalyst particles.

[0006] With the low-dust concept, the selective catalytic reduction is provided following the flue-gas desulfurization such that additional loads by SO2 and dust will be eliminated, the catalyst thus having an accordingly extended dwell time. However, this involves the drawback of the flue gases only having temperatures of below 200° C. so as to require reheating for the catalytic denitrification. An accordingly high additional demand of energy will thus be required.

[0007] In the prior art, e.g. DE 196 12 240 A1 and DE 196 12 240 A2, solutions in which the catalyst is added to the flue-gas stream in powdery form and separated on a bag filter together with the dust also have already been proposed. The reduction in those cases takes place during the flow of the flue gases toward the bag filter. The catalyst is subsequently periodically blown off with the bag filter hot air while being regenerated. However, this entails an additional load of dust on the filter, thus calling for more frequent cleaning of the same.

[0008] It is the object of the present invention to provide a plant for the removal of nitrogen oxides from flue gases according to the selective catalytic reduction (SCR) technology and a method therefor, which comprise reduced energy consumptions as compared to low-dust concepts and increased catalyst dwell times as compared to high-dust plants.

[0009] This object of the invention is achieved by the initially defined plant in which the dust separation means is comprised of at least a first and a second filter device and the reduction catalyst is arranged between the first and second filter devices, as well as by method for purifying the flue gases from a furnace, in which the flue gases are supplied to a first dust separation prior to contacting the reduction catalyst, and the fine-dust purification of the flue gases is effected after the reduction of the nitrogen oxides.

[0010] It was surprisingly found that, for the use of conventional catalyst beds which are not specifically formed for high-dust operation, it is not necessary to dedust the flue gases at least nearly completely, but that a pre-dedusting step or coarse-dust separation performed prior to the catalytic reduction will do for the operation of the catalyst bed without substantially shortening the dwell time of the catalyst.

[0011] In this respect, it should be noted that “coarse-dust separation” and “fine-dust separation” do not necessarily refer to particle sizes, but rather to the dust load of the flue gas itself, i.e. the portion of dust particles present in the flue gas.

[0012] The catalyst configuration for the removal of nitric oxides according to the invention offers the advantage that the flue gases need not be additionally heated for the denitrification reactions, but still have inherently sufficient energy contents, i.e. sufficiently high temperatures, to enable the operation of the catalyst. A reduction of fuels is thus feasible as compared to low-dust plants.

[0013] The first filter device can be arranged immediately following the furnace or a heat exchanger unit, viewed in the flow direction of the flue gases, such that the flue gases will enter the first filter unit at a very high temperature, whereby the temperature drop in this filter unit can be kept low—considered relatively—and the flue gases will leave the filter device at a temperature promoting the reduction of the nitrogen oxides on the catalyst.

[0014] By high temperature, a temperature of at least 250° C. is understood.

[0015] Yet, it may also be envisaged to arrange a desulfurization plant between the first filter device and the furnace, or a heat exchanger unit following thereupon, viewed in the flow direction of the flue gases, such that the sulfur content will at least be proportionally reduced and the risk of sulfur compounds depositing on the catalyst will be lowered.

[0016] In a particularly preferred manner, the first filter device is comprised of an electric filter. This has the advantage that, on the one hand, this filter can be operated at a high temperature and, on the other hand, this filter technology is already highly mature and electric filters are available, anyway, for instance, in cement production plants—dedusting formerly having been frequently performed with electric filters, yet the majority of those electric filters having been replaced with cloth filters due to tightened environmental regulations—and no additional investment costs will occur.

[0017] It is, furthermore, possible that at least one raw material drying apparatus or raw material dry-grinding apparatus is arranged between the first filter device and the second filter device, in particular between the second filter device and
the catalyst, viewed in the flow direction of the flue gases, such that the residual energy contents of the flue gases can be used for drying the raw materials which are, for instance, employed for the production of cement. In addition, it will be achieved that the flue gases leaving the catalyst bed will even be further cooled prior to entering the second filter device, which is preferably formed by a cloth filter, said second filter device thus being subjected to a reduced thermal stress even without applying additional cooling means.

[0018] The dust content of the flue gases in the first dust separation is preferably reduced to a maximum dust content of 3 g/Nm³, in particular 2.5 g/Nm³, for instance 1 g/Nm³, or a maximum dust content of 30 g/Nm³, respectively, if another pre-separation means, i.e. no electric filter, is used as said first filter device, since it has turned out that the efficiency of the plant can be enhanced by these maximum dust contents of the flue gases.

[0019] It is, furthermore, possible to perform the first dust separation at a temperature of the flue gas of at least 250°C. or at most 450°C., for instance at most 350°C., whereby, as already pointed out above, no special measures need to be taken to reduce the temperature drop in the first filter device, and the latter can hence be configured in a more cost-effective manner.

[0020] For a better understanding of the invention, the latter will be explained in more detail by way of the following FIGURE.

[0021] In a schematically strongly simplified manner, FIG. 1 illustrates a plant according to the invention in the form of a block diagram.

[0022] To begin with, it should be noted that positional indications given in the description, such as e.g. upstream, after or downstream, laterally etc., refer to the FIGURE actually described and illustrated and any positional change is to be analogously transferred to the new position.

[0023] FIG. 1 depicts a plant 1 for the production of cement clinker.

[0024] It has already been mentioned in the beginning that the nitrification plant according to the invention is not limited to its use in the cement industry, although this is the preferred variant embodiment. It is also possible to equip waste incineration plants, calorific power stations, etc. with the same.

[0025] The plant 1 comprises a furnace 2 in the form of a rotary kiln which is operated by a firing device 3 so as to produce cement clinker from known raw materials.

[0026] The flue gases leaving the furnace—arrow 4—are introduced into a heat exchanger unit 5, which in the present variant embodiment is designed as a cyclone heat exchanger comprising four cyclones, to utilize the energy contents of the flue gases for preheating the charged raw meal.

[0027] The flue gas leaving the heat exchanger unit 5—arrow 6—subsequently enters the gas purification plant. The gas purification plant comprises a first filter device 7, a reduction catalyst 8 and a second filter device 9.

[0028] The first filter device 7 is configured as an electric filter. The flue gas entering the electric filter may optionally be pre-conditioned with water in order to increase the effectiveness of the electric filter. To this end, a spray device 11 can be arranged in a supply line 10 leading to the first filter device 7 to spray water into the same.

[0029] It is, furthermore, possible that the flue gas is diluted with fresh air via a fresh-air duct 12 including a valve 13, so as to enable an increase in the effectiveness of coarse dedusting through the electric filter. Alternately or additionally, a mixed gas can be supplied to the flue gas via a mixed-gas line 14, for instance a gas derived from the furnace 2, a so-called bypass gas, which can be drawn off the furnace 2 in the region of the heat exchanger unit 5.

[0030] Appropriate conveying means 15, e.g. flue gas fans, can be arranged both in the mixed-gas line 14 and in the supply line 10.

[0031] The dust content of the flue gas or crude gas is reduced by the first filter device 7 from 200 g/Nm³ to 300 g/Nm³ or 60 g/Nm³ to 70 g/Nm³, respectively, to a maximum value of 3 g/Nm³ and, preferably, 1 g/Nm³. It is also possible to reduce the dust content only to a maximum of 30 g/Nm³, if no electric filter but another pre-separation means is used as said first filter device 7.

[0032] The first filter device 7 can be provided with a heat insulation suitable for such high temperatures so as to lower the decrease of the flue gas temperature.

[0033] After this, the flue gas enters the reduction catalyst 8, where the denitration, i.e. the reaction of nitric oxides to nitrogen and water, takes place according to known reactions. In doing so, it is provided that a reducing agent is fed to the pre-purified flue gas, using a reducing-agent feeder 16. As a rule, the reducing agent is comprised of ammonia, as is known from the prior art. Yet, the use of compounds containing ammonia or reducing agents releasing ammonia at elevated temperatures may also be envisaged.

[0034] The reducing-agent feeder 16 may also be omitted if excess ammonia is present in the flue gas of the plant 1, and, if there is insufficient ammonia, it is also possible to supplement the missing portion via the reducing-agent feeder 16.

[0035] The catalyst may, for instance, be comprised of titanium dioxide or vanadium pentoxide or titanium oxide as the carrier and vanadium pentoxide as the active mass, optionally supplemented with tungsten oxide or mixed with other metal oxides. In principle, these catalysts are known from the prior art so that any further discussion as to their geometries or pore structures can be obviated.

[0036] The supply of reducing agent again is, for instance, effected through spraying nozzles.

[0037] The reducing agent itself can be admixed to the flue gas up-stream of the catalyst, yet the reducing agent is preferably fed into or onto the catalyst bed.

[0038] The formation of the catalyst bed per se is also known from the prior art such that in this respect it is referred to the pertinent literature. It is, in particular, possible to provide the reduction catalyst on several superimposed levels, through which the flue gas will successively flow.

[0039] Via a line 17, the denitrified flue gas—it should be noted here that by denitrified flue gas a flue gas is meant which, in terms of NOₓ, complies with the exhaust emission standards, e.g. the Austrian exhaust emission standards—reaches the second filter device 9. This second filter device 9 is configured as a bag filter comprising filter cloths or filter bags. Such bag filters are already known and used in the cement industry such that any further discussion can be obviated. By the aid of these filter cloths, the dust content of the flue gas is at least reduced to values complying with the exhaust emission standards.

[0040] If required, a spray cooler 18 can be arranged upstream of the second filter device 9 to cool the flue gas prior to entering the second filter device 9 to a temperature, for instance a maximum temperature of 250°C., at which the thermal stress exerted on the filter cloth by the flue gas will be reduced.
After the second filter device 9, the thus purified flue gases leave the plant 1 into the air via a stack 19.

To this end, a conveying means 15 may again be arranged between the stack 19 and the second filter device 9.

The residual energy contents of the flue gases leaving the reduction catalyst 8 are, however, preferably used to dry the raw materials used for cement production. To this end, two drying mills 20 are illustrated in Fig. 1, which are arranged between the reduction catalyst 8 and the second filter device 9, viewed in the flow direction of the flue gases. The two drying mills 20 are, in particular, arranged in parallel such that the denitrified flue gases will flow through the same either simultaneously or alternately. Valves 21-24 are illustrated in Fig. 1 for the respective switching of the flow paths of the flue gases. It is, furthermore, shown that it is also possible to arrange the drying mills 20 in parallel with the direct introduction of the flue gases via line 17 into the second filter device 9, to which end a valve 25 is again arranged in line 17 in order to enable switching between the flow directions via line 17 or via at least one of the drying mills 20.

The drying mills 20 themselves are configured according to the prior art.

Another option is to supply fresh air via a fresh-air duct 26 to at least one of the drying mills 20, a respective fresh-air valve 27 being arranged in the fresh-air duct 26 also in this case.

It is, furthermore, possible to admix at least a portion of the flue gases that have left the drying mills 20 to the flue gases supplied from the reduction catalyst 8 to the drying mills 20 so as to further exploit the energy contained in these flue gases as circulating air via a circulating-air duct 28 including a circulating-air valve 29.

With this so-called “mill operation”, the denitrified flue gas will reach the second filter device 9 at a temperature of about 150° C.

In the context of the invention it is also possible to use more than two filter devices 7, 9 and to arrange several reduction catalysts 8 in series or in parallel. Moreover, more than two, or only one of the, drying mills 20 can be operated in the sense of the invention.

Although not illustrated, there is the option, as already pointed out above, to arrange a desulfurization plant between the furnace 2 and the first filter device 7, or between the heat exchanger unit 5 and the first filter device 7, which may correspond to the prior art, in order to reduce the sulfur content, i.e. the content of SO₂ in the flue gas at least proportionally.

During the operation of the plant 1, the following measured values were obtained by appropriate sensors on the respective locations:

- Dust content of the flue gas leaving the furnace 2 and/or the heat exchanger 5: 60 to 120 g/Nm³
- Dust content of the flue gas leaving the electric filter: max. 3 g/Nm³
- Content of NO₂ after the reduction catalyst: less than 100 mg NO₂/Nm³
- Temperature of the flue gas after the electric filter: 300° C. to 340° C.
- Temperature of the flue gas following the reduction catalyst 8: 280° C. to 320° C.
- Temperature of the flue gas at the entry into the bag filter: max. 250° C.

Dust content of the flue gas at the entry into the bag filter: less than 3 g/Nm³ with direct introduction and about 100 g/Nm³ with “mill operation”, respectively

Dust content of the flue gas when leaving the bag filter: 10 mg/Nm³

As is, in particular, apparent from the above measurements, the dust content of the flue gas is practically not reduced in the reduction catalyst 8. If, however, a dust precipitate does occur in the reduction catalyst 8, this can be periodically cleaned, e.g. by purging with compressed air.

According to a variant embodiment of the invention, it is possible to use, as an alternative or addition to the nitric oxides, also the flue gas of carbon monoxide from, particularly odor-forming, hydrocarbons and/or the removal of ammonia from flue gases from combustion furnaces, particularly from plant 1. To this end, a separate catalyst can, if required, be arranged upstream or downstream of the denitri- fication catalyst, comprising, for instance, titanium- vanadium compounds which may be supplemented with palladium and/or platinum. Such catalysts are known from the prior art so that reference is made to the pertinent literature.

To this end, the reduction catalyst 8 can be configured as a layered catalyst including several beds for the individual catalysts, or several catalysts can be separately arranged in the plant 1 or a respective flue gas purification plant, for instance, one behind the other in separate containers, viewed in the flow direction of the flue gases.

For good order’s sake, it should finally be pointed out that, for a better understanding of the structure of plant 1, the latter and its components have partially been illustrated out of scale and/or enlarged and/or downscaled.

LIST OF REFERENCE NUMERALS

- 1 plant
- 2 furnace
- 3 firing device
- 4 arrow
- 5 heat exchanger unit
- 6 arrow
- 7 filter device
- 8 reduction catalyst
- 9 filter device
- 10 supply line
- 11 spray device
- 12 fresh-air duct
- 13 valve
- 14 mixed-gas device
- 15 conveying means
- 16 reducing agent
- 17 line
- 18 spray cooler
- 19 stack
- 20 drying mill
- 21 valve
- 22 valve
- 23 valve
- 24 valve
- 25 valve
- 26 fresh-air duct
- 27 fresh-air valve
- 28 circulating-air duct
- 29 circulating-air valve
9. A plant for purifying flue gas from a furnace, the plant comprising:
   at least one selective reduction catalytic converter for reducing nitrogen oxides present in the flue gas and/or a catalytic converter for reducing carbon monoxide, hydrocarbons, and/or ammonia;
   an optional reducing-agent feed device; and
   at least one first filter device formed of at least one selective reduction catalytic converter disposed between said first and second filter devices.
10. The plant according to claim 9, wherein the furnace is a cement rotary kiln.
11. The plant according to claim 9, wherein said first filter device is disposed substantially immediately following the furnace or a heat exchanger unit, in a flow direction of the flue gas.
12. The plant according to claim 9, which further comprises a desulfurization plant disposed between said first filter device and the furnace, in a flow direction of the flue gas.
13. The plant according to claim 9, which further comprises a heat exchanger unit connected immediately following the furnace in a flow direction of the flue gas, and a desulfurization plant disposed between said heat exchanger unit and said first filter device in the flow direction of the flue gas.
14. The plant according to claim 9, wherein said first filter device is an electric filter.
15. The plant according to claim 9, which further comprises at least one raw material drying apparatus connected between said catalytic device and said second filter device, in a flow direction of the flue gas.
16. A method of purifying flue gas generated in a furnace, which comprises:
   providing the plant according to claim 9 connected to the furnace;
   guiding the flue gas from the furnace to the first filter device of the dust separation device;
   subsequently conducting the flue gas into contact with a selective reduction catalytic converter for selective catalytic reduction of nitrogen oxides by a reducing agent and/or at least one catalytic converter for reducing carbon monoxide, hydrocarbons, and/or ammonia; and
   subsequently subjecting the flue gas to a fine-dust purification by filtering dust from the flue gas in the second filter device of the dust separation device.
17. The method according to claim 16, wherein the flue gas is generated in a cement rotary kiln.
18. The method according to claim 16, which comprises reducing a dust content of the flue gas in the first filter device to a maximum dust content of 30 g/m³N before the flue gas is conducted to the catalytic device.
19. The method according to claim 18, which comprises reducing a dust content of the flue gas in the first filter device to a maximum dust content of 3 g/m³N.
20. The method according to claim 19, which comprises reducing a dust content of the flue gas in the first filter device to a maximum dust content of 2.5 g/m³N.
21. The method according to claim 16, which comprises carrying out a first dust separation in the first filter device at a temperature of the flue gas of at least 250°C.
22. A method of purifying flue gas generated in a furnace, which comprises:
   guiding the flue gas from the furnace to a first filter device of the dust separation device and subjecting the flue gas to a first dust separation;
   subsequently conducting the flue gas for contact with a selective reduction catalytic converter for selective catalytic reduction of nitrogen oxides with a reducing agent and/or a catalytic converter for the reduction of carbon monoxide, hydrocarbons, and/or ammonia; and
   subsequently, following the catalytic reduction, subjecting the flue gas to a fine-dust purification in a second filter device of the dust separation device.
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