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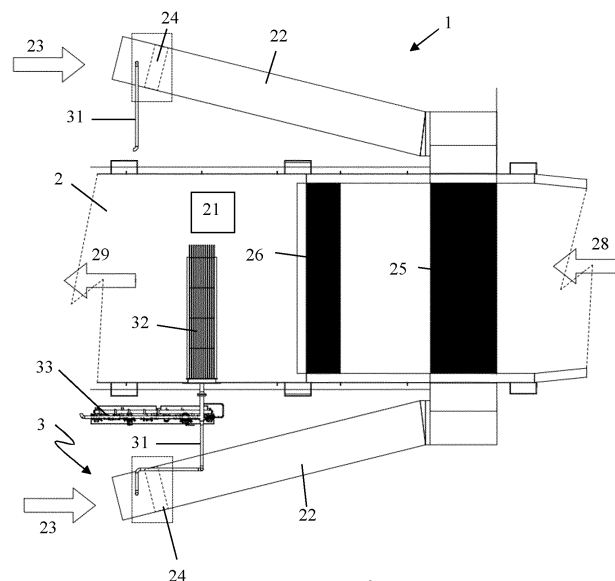
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(54) **SYSTEM AND METHOD TO REDUCE ENVIRONMENTALLY HARMFUL GASES OUT IN A FLUE GAS PRODUCED BY A FUELED POWER GENERATOR**

(57) The present disclosure relates to reduction system 1 for flue gas produced by a fuelled power generator, comprising an exhaust duct arrangement 2 with a flue gas passage, and a reduction agent injection system 3. The latter comprises one or more vaporizers for vaporizing a liquid reduction agent to a vapor, and one or more injectors for injecting the vapor into a respective cooling fluid passage 22. One or more mixers located in a respective cooling fluid passage are configured to mix the cooling fluid with the vapor injected in the cooling fluid passage, obtaining a reduction agent-cooling fluid mixture.

A mixing unit 25 with a static turbulence creating system located in the flue gas passage 21 is configured to obtain a homogeneous cooled flue gas mixture out of the reduction agent-cooling fluid mixture and the hot flue gas. At least one SCR catalyst 26 placed in the flue gas passage downstream the mixing unit removes NO_x out of the cooled flue gas mixture. Also a CO reduction catalyst can be provided, separated from or integrated with the SCR catalyst, to remove CO out of the cooled flue gas mixture.

**FIG. 1**

Description

Technical field

[0001] The present disclosure relates to purification of flue gases having one or more environmentally harmful gases originating from fossil fuelled power generators or power generators fuelled by green fuels. The present disclosure more in particular relates to purification of environmentally harmful gases such as nitrogen oxides (NO_x) and carbon monoxide (CO) out of these flue gases.

Background

[0002] Fuelled powered generators discharge flue gases having various environmentally harmful gases produced during the combustion of the fossil fuel, including carbon monoxide (CO), nitrogen oxides (NO_x), etc.. Since the regulations on the amount of these harmful gases that can be discharged into the atmosphere have been strengthened, there exists a need to improve the known systems for flue gas cleaning.

[0003] It is known to use catalytic processes to clean NO_x and CO out of flue gases originating from fuelled power generators. The standard known and applied catalysts are able to work at temperatures up to 470°C, which is lower than the flue gas temperatures of most of the fuelled power generators before any cooling is applied, which is normally approximately between ± 500°C and 700°C. In order to cool down the flue gas, it is known to apply a heat recovery system or a "dilution" or "tempering" system, which is a system that supplies a cooling fluid such as ambient air to the flue gas to cool down the flue gas stream to a temperature appropriate for it to be treated with the catalysts. The process in which the flue gas is cooled down using a cooling fluid to enable an SCR catalyst to remove NO_x out of the flue gas is called "dilution-SCR" or "tempering-SCR".

[0004] In EP 3 529 466, for instance, a dilution-SCR for a fossil fuel powered engine is described. Therein, an exhaust duct arrangement for a fossil fuel powered engine is disclosed, comprising a flue gas passage, a cooling fluid passage, a mixing device for mixing cooling fluid with the hot flue gas and a selective catalytic reduction (SCR) catalyst for removing NO_x arranged in the flue gas passage, and at least a first means for supplying a reduction agent. The mixing device comprises a mixing chamber with a first wall and an opposed second wall, this first and second wall arranged upstream of the SCR in the flue gas passage and extending over the cross-sectional area of the flue gas passage, both walls perforated by through holes, wherein through holes of the first wall are connected with through holes of the second wall in pairs by pipes extending through the mixing chamber, wherein the pipes are perforated by at least one hole into the mixing chamber and the cooling fluid passage ending into the mixing chamber.

[0005] There currently exist also other tempered SCR

(TSCR)-systems which have another configuration of a mixing unit which comprises a static turbulence creating system which is configured to create a turbulence inside the mixing unit during operation in the cooling fluid and the flue gases, in such a way homogeneously mixing these, resulting in a cooled flue gas mixture with a homogeneous temperature which can then be emitted by the mixing unit further into the reduction system.

[0006] It is a goal of the present disclosure to provide in a suitable configuration of a catalytic system to reduce harmful gases, more in particular NO_x and CO, in flue gas originating from a fuelled power generator which is arranged with a mixing unit which is provided with a static turbulence creating system which is configured to create a turbulence inside the mixing unit during operation and to homogeneously mix a cooling fluid and the hot flue gases originating from the fuelled power generator, resulting in a cooled flue gas mixture with a homogeneous temperature. It's a further goal of the present disclosure to provide such a configuration having a minimized amount of separate tools necessary to cool down the hot flue gas originating from the fuelled power generator to a temperature which is workable by the one or more catalysts, and to apply a NO_x reduction agent to reduce the amount of NO_x in the flue gas. It is still a further goal of the present disclosure to provide such a configuration which results in a good distribution of the NO_x reduction agent in the flue gas.

Summary

[0007] According to a first aspect of the present disclosure, a reduction system to reduce environmentally harmful gases out of flue gas produced by a fuelled power generator, wherein the reduction system comprises

- an exhaust duct arrangement comprising
 - a flue gas passage configured to receive the flue gas produced by the fuelled power generator and configured to let the flue gas flow through it, and
 - one or more cooling fluid passages that are configured to draw in cooling fluid and to let cooling fluid flow through it, and
- in order to reduce NO_x as a harmful gas in the flue gas, a NO_x reduction agent injection system, comprising
 - one or more vaporizers for vaporizing a liquid NO_x reduction agent to a NO_x reduction agent vapor, wherein the one or more vaporizers optionally are heat exchangers, and
 - one or more injectors which each are fluidically connected with one of the one or more vaporizers, wherein the one or more injectors each at least partially extend in one of the one or more

cooling fluid passages that are configured to draw in cooling fluid, and wherein the injectors are configured to inject the NO_x reduction agent in the cooling fluid present in the respective cooling fluid passage,

◦ one or more mixers located in the one or more cooling fluid passages upstream of the one or more injectors, and configured to mix the cooling fluid with the NO_x reduction agent, which is in operation injected by the one or more injectors in the respective cooling fluid passage, obtaining a reduction agent-cooling fluid mixture,

◦ a mixing unit located in the flue gas passage, the mixing unit being configured to draw in hot flue gas from the flue gas passage, and being fluidically connected with the one or more cooling fluid passages allowing reduction agent-cooling fluid mixture to be drawn in, and comprising a static turbulence creating system which is configured to create a turbulence in the hot flue gas and the reduction agent-cooling fluid present in the mixing unit during operation, in that way homogeneously mixing the reduction agent-cooling fluid mixture with the hot flue gases, resulting in a cooled flue gas mixture, and the mixing unit further being configured to emit the cooled flue gas mixture in the flue gas passage with a homogeneous temperature throughout the cooled flue gas mixture, and

- at least one selective catalytic reduction (SCR) catalyst located in the flue gas passage downstream the mixing unit, the SCR catalyst being configured to remove NO_x from the cooled flue gas mixture.

[0008] The fuels can be fossil fuels, which are defined as "hydrocarbon-containing materials such as coal, oil, natural gas, formed naturally in the Earth's crust from the remains of dead plants and animals that is extracted and burned as a fuel", as well as green fuels which are defined as "different types of fuel that are derived from organic matter, renewable and eco-friendly, or less toxic than conventional fuels, and that can be made from plants, animal materials, waste, or chemicals". An example of a green fuel is green hydrogen.

[0009] An advantage of this reduction system according to the present disclosure as described above is that the reduction agent vapor, which is a gas, is introduced in another gas, i.e. the cooling fluid, through which it is easy to mix, and prevents corrosion of parts or walls of the reduction system. Furthermore, because of the high air flow in the exhaust duct arrangement created by the mixing unit (a high air flow meaning an air flow which is more than 100 times higher than the flow of the reduction agent), the reduction agent vapor can be added to the cooling fluid with an increase in the relative humidity which stays below 100 %, through which no recondensation can take place. Another advantage of this reduction

system according to the present disclosure as described above is that the cooling of the flue gas to a temperature appropriate to enable the one or more catalysts to reduce the nitrogen oxides, and optionally the carbon monoxide, and the distribution of the NO_x reduction agent before the one or more SCR catalysts, are performed by one and the same element, i.e. the mixing unit, saving equipment and costs and simplifying the reduction system. Furthermore, this reduction system provides in a high uniformity of the velocity, the reagent and the temperature distribution of the flue gas to be treated.

[0010] In an optional embodiment of a reduction system according to the present disclosure, the vaporizer is located downstream the at least one SCR catalyst. The advantage thereof is that the heat from the flue gas is used to vaporize the liquid NO_x reduction agent. This thus minimizes the necessary equipment.

[0011] In an optional embodiment of a reduction system according to the present disclosure, the NO_x reduction agent injection system comprises a liquid reduction agent flow control unit to control the amount of liquid NO_x reduction agent to be vaporized depending on the demand of the NO_x reduction agent.

[0012] In a specific embodiment of a reduction system according to the present disclosure, the NO_x reduction agent is ammonia, and the vaporizers are configured to vaporize an aqueous ammonia solution to a hot ammonia / water vapor.

[0013] In a more specific embodiment of a reduction system according to the present disclosure, the vaporizer is a heat exchanger.

[0014] In a specific embodiment of a reduction system according to the present disclosure, the NO_x reduction agent injection system is an ammonia injection system, and the liquid NO_x reduction agent flow control unit is an aqueous ammonia flow control unit to control the amount of aqueous ammonia solution to be vaporized depending on the ammonia demand.

[0015] In a particular embodiment of a reduction system according to the present disclosure, the exhaust duct arrangement comprises two cooling fluid passages. Both are always working during the operation of the reduction system. The advantage thereof is that when the delivery of cooling fluid in one of these cooling fluid passages would fail, the other one will still be supplied with cooling fluid through which there is a constant delivery of ammonia / water vapor to the SCR catalyst(s).

[0016] In a possible embodiment of a reduction system according to the present disclosure, the cooling fluid is a cooling gas or ambient air or a mixture of cooling air / gas with steam or vapor or droplets of a liquid.

[0017] In a specific embodiment of a reduction system according to the present disclosure, the cooling fluid has a temperature of between 5°C and 45°C. When the cooling fluid is ambient air, the temperature depends on the weather conditions of the environment where the reduction system is installed.

[0018] In a particular embodiment of a reduction sys-

tem according to the present disclosure, the NO_x reduction agent vapor has a temperature of between 110°C and between 400°C, more in particular between 150°C and 250°C. It is remarked that the temperature of the NO_x reduction agent vapor depends on the amount of dosed NO_x reduction agent, which in its turn depends on the flue gas temperature and the amount of NO_x to be reduced. If the flow rate of the NO_x reduction agent is at its maximum, for instance during operation of the fuelled power generator, then the temperature of the NO_x reduction agent vapor will be towards the lower temperature of the temperature range, while when the flow rate of the NO_x reduction agent is low, for instance when there is a low demand of NO_x reduction agent in case the power generator is changing from one load case to another or at start-up, then a minor amount of NO_x has to be reduced, often approaching the NO_x emission limit, and then the temperature of the NO_x reduction agent vapor will be towards the higher temperature of the temperature range.

[0019] In an optional embodiment of a reduction system according to the present disclosure, in order to reduce CO as a harmful gas out of the flue gas, one or more CO reduction catalysts located downstream the mixing unit are provided, the one or more CO being arranged either separately downstream or upstream of the one or more SCR catalysts, either as a whole together with the one or more SCR catalysts, i.e. integrated with or united with the one or more SCR catalysts. In the latter case, for instance a dual catalyst can be used.

[0020] According to a second aspect of the present disclosure, a method to reduce one or more environmentally harmful gases in flue gas produced by a fuelled powered generator, the method comprising the steps of

- directing hot flue gas from the fuelled power generator to a flue gas passage of an exhaust duct arrangement and letting the hot flue gas flow through the flue gas passage;
- entering cooling fluid in one or more cooling fluid passages of the exhaust duct arrangement and letting the cooling fluid flow through these;
- in order to reduce NO_x as a harmful gas out of the flue gas,
 - vaporizing a liquid NO_x reduction agent to a reduction agent vapor using one or more vaporizers;
 - injecting the NO_x reduction agent vapor in cooling fluid present in the respective cooling fluid passage using one or more injectors that each extend at least partially in one of the one or more cooling fluid passages and that each are in fluidical connection with one of the one or more vaporizers;
 - mixing the injected NO_x reduction agent vapor and the cooling fluid in the respective cooling fluid passage using one or more mixers each

located in one of the one or more cooling fluid passages downstream of the respective one or more injectors, obtaining a reduction agent-cooling fluid mixture in the respective cooling fluid passage;

- directing the NO_x reduction agent-cooling fluid mixture in the respective cooling fluid passage towards a mixing unit located in the flue gas passage, the mixing unit comprising a static turbulence creating system,
- creating turbulence in the reduction agent-cooling fluid mixture and the hot flue gas present inside the mixing unit by means of the static turbulence creating system, in that way homogeneously mixing of the reduction agent-cooling fluid mixture with the hot flue gases, resulting in a cooled flue gas mixture;
- emitting the cooled flue gas mixture with a homogeneous temperature by the mixing unit in the flue gas passage;
- directing the cooled flue gas mixture to at least one SCR catalyst, and removing NO_x out of the cooled flue gas mixture.

[0021] It is the intention that an amount of NO_x is removed out of the cooled flue gas mixture until an amount of NO_x according to the current limits as described in the environmental norms or even a lower amount of NO_x is reached.

[0022] In an optional embodiment of a method according to the present disclosure, in order to reduce CO as a harmful gas out of the flue gas, the method comprises the step of removing CO out of the cooled flue gas mixture by means of at least one CO reduction catalyst located downstream the mixing unit, either separately downstream or upstream of the one or more SCR catalysts, either as a whole together with, i.e. integrated with, the one or more SCR catalysts. It is the intention that an amount of CO is removed out of the cooled flue gas mixture until an amount of CO according to the current limits as described in the environmental norms or even a lower amount of CO is reached.

[0023] In a specific embodiment of a method according to the present disclosure, the NO_x reduction agent is ammonia, and wherein the liquid NO_x reduction agent is an aqueous ammonia solution and the NO_x reduction agent vapor is ammonia / water vapor.

[0024] In a particular embodiment of a method according to the present disclosure as described above, a reduction system according to the present disclosure as described above is used.

[0025] According to a third aspect of the present disclosure, a NO_x reduction agent injection system for a reduction system for reducing one or more environmentally harmful gases out of a flue gas produced by a fuelled power generation, the reduction system comprising an exhaust duct arrangement which comprises

- a flue gas passage configured to draw in hot flue gas produced by the fuelled power generator and configured to allow the flue gas to flow through it;
- one or more cooling fluid passages configured to draw in cooling fluid and configured to allow the cooling fluid flow through it;
- a mixing unit located in the flue gas passage, the mixing unit comprising a static turbulence creating system which is configured to create a turbulence in the gases present in the mixing unit during operation, in that way homogeneously mixing the gases, resulting in a homogeneous gas mixture, and the mixing unit further being configured to emit the homogeneous gas mixture in the flue gas passage with a homogeneous temperature throughout the homogeneous gas mixture;
- at least one SCR catalyst located in the flue gas passage downstream the mixing unit, and

wherein the NO_x reduction agent injection system comprises

- one or more vaporizers for vaporizing a liquid NO_x reduction agent to a NO_x reduction agent vapor, the one or more vaporizers being configured to be located in the flue gas passage, and
- one or more injectors which each are fluidically connected with one of the one or more vaporizers, the one or more injectors each being configured to at least partially extend into one of the one or more cooling fluid passages, and which are configured to inject the NO_x reduction agent vapor in the cooling fluid present in the respective cooling fluid passage,
- one or more mixers that are configured to be located in one of the one or more cooling fluid passages upstream of the one or more injectors, and which are configured to mix the cooling fluid with the NO_x reduction agent vapor which is in operation injected in the respective cooling fluid passage, obtaining a reduction agent-cooling fluid mixture, and

wherein

- the mixing unit is configured to draw in hot flue gas from the flue gas passage, and is fluidically connected with the one or more cooling fluid passages allowing reduction agent-cooling fluid mixture to be drawn in, and wherein the static turbulence creating system is configured to create a turbulence in the reduction agent-cooling fluid mixture and the hot flue gas present in the mixing unit during operation, in that way homogeneously mixing the reduction agent-cooling fluid mixture and the hot flue gas, resulting in a cooled flue gas mixture, and wherein the mixing unit is further configured to emit the cooled flue gas mixture in the flue gas passage with a homogeneous temperature throughout the cooled flue gas mixture, and

- the one or more SCR catalysts are configured to remove NO_x from the cooled flue gas mixture.

[0026] In an optional embodiment of a NO_x reduction agent injection system according to the present disclosure, the vaporizer is located downstream the at least one selective catalytic reduction catalyst.

[0027] In a particular embodiment, a NO_x reduction agent injection system according to the present disclosure as described above for a NO_x reduction system according to the present disclosure as described above is disclosed.

[0028] According to a final aspect of the present disclosure, a power production plant is disclosed comprising one or more fuelled power generators and one or more reduction systems to reduce one or more environmentally harmful gases out of the flue gases produced by the fuelled power generator according to the present disclosure as described above, wherein each of the one or more fuelled power generators is fluidically connected with the one or more reduction systems.

Description of the figures

[0029] FIG. 1 shows a cross-sectional view of an exemplary embodiment of a reduction system according to the present disclosure.

Detailed description

[0030] The present disclosure relates to a reduction system to reduce environmentally harmful gases, more in particular NO_x (nitrogen oxides) and CO (carbon monoxide) in flue gas (or exhaust gas) originating from a fuelled power generator. With NO_x is meant NO as well as NO₂. Examples of fuels can be fossil fuels such as coal, natural gas or fuel oil, but can also be green fuels such as green hydrogen. An example of a fuelled power generator is a turbine, such as simple cycle gas turbine.

[0031] The reduction system comprises an exhaust duct arrangement which in its turn comprises a flue gas passage configured to receive hot flue gas with a temperature of between 450°C and 700°C from the fuelled power generator. This temperature of this flue gas is way too high to be able to treat the flue gas with a standard SCR catalyst which normally operates in temperature intervals between 260°C and 470°C, more in particular between 420°C and 450°C. Therefore, the flue gas needs to be cooled down to a temperature which is workable by such an SCR catalyst.

[0032] To this end, the exhaust duct arrangement is designed as described in the following paragraphs.

[0033] The exhaust duct arrangement first of all comprises one or more cooling fluid passages configured to draw in cooling fluid and to let cooling fluid flow through it. This cooling fluid for instance is ambient air taken from the surroundings of the cooling fluid passage(s). It can however also be a cooling gas or a mixture of cooling air /

gas with steam or vapor or droplets of a liquid. The temperature of the cooling fluid is typically between 5°C and 45°C. When ambient air is used, the temperature thereof is depending on the weather conditions of the environment where the reduction system is located. These one or more cooling fluid passages each are in fluidical connection with a mixing unit located in the flue gas passage. This mixing unit comprises a static turbulence creating system configured to create turbulence in a gas mixture present in the mixing unit, such that the gases of the gas mixture are homogeneously mixed, resulting in a homogeneous gas mixture. Further, the mixing unit is configured to emit this homogeneous gas mixture into the flue gas passage, wherein this homogeneous gas mixture has a homogeneous temperature throughout the gas mixture.

[0034] For the removal of the NO_x out of the flue gas, a catalytic process is applied using at least one SCR catalyst which is located in the flue gas passage downstream of the mixing unit. These one or more SCR catalysts are used in combination with a NO_x reduction agent. The applied SCR catalysts are standard catalysts as commonly known by a man skilled in the art. An example of a material of such an SCR catalyst is a combination of vanadium pentoxide (V₂O₅) and titanium dioxide (TiO₂).

[0035] When it is necessary to also reduce the amount of CO in the flue gas produced by the fuelled power generator, one or more CO reduction catalysts are used. These CO reduction catalysts are located in the flue gas passage either separately downstream or upstream of the one or more SCR catalysts, either as a whole together with or integrated with the one or more SCR catalysts.

[0036] The amount of NO_x and the amount of CO are more in particular reduced to an amount which is equal to or below the allowed limit as described in the currently applicable emission norms.

[0037] The NO_x reduction agent is injected by means of a NO_x reduction agent injection system. This NO_x reduction agent injection system comprises one or more injectors that each extend partially in the one or more cooling fluid passages. To that end, the end of each the one or more injectors is located in the respective cooling fluid passage. Since it is difficult to mix a liquid NO_x reduction agent with a gaseous cooling fluid, and since when mixing a liquid with a gas, re-condensation can take place causing corrosion on parts and walls of the reduction system, one or more vaporizers, more in particular in the form of heat exchangers, are provided to vaporize the liquid NO_x reduction agent to a NO_x reduction agent vapor. In this way, a gas is mixed with a gas which is an easy process to do, and which does not lead to re-evaporation. The liquid NO_x reduction agent is in general stored in one or more reservoirs. The one or more vaporizers are located in the flue gas passage, more in particular downstream the at least one SCR catalyst, and if one or more CO reduction catalysts are present, also downstream the one or more CO reduction catalysts. The

NO_x reduction agent vapor is then injected in the cooling fluid present in the respective cooling fluid passage by means of the one or more injectors. Upstream of these one or more injectors in the respective cooling fluid passage, one or more mixers are provided for mixing the cooling fluid present in the cooling fluid passage(s) with the NO_x reduction agent vapor which is injected in the respective cooling fluid passage. This results in a reduction agent-cooling fluid mixture.

[0038] The NO_x reduction agent is more in particular ammonia. During operation, an aqueous ammonia solution (with a typical concentration of between 19 and 29 wt.% ammonia in water) is vaporized to an ammonia / water vapor. This ammonia / water vapor more specifically has a temperature of between 110°C and 400°C.

[0039] The reduction agent-cooling fluid mixture is then injected in the flue gas using the mixing unit. This mixing unit is in fluidical connection with each one of the one or more cooling fluid passages. The mixing unit is in other words configured to draw in reduction agent-cooling fluid mixture from the one or more cooling fluid passages, and also to draw in the hot flue gas which flows through the flue gas passage. The mixing unit is configured to create a turbulence in the reduction agent-cooling fluid mixture and the hot flue gas which were drawn in the mixing unit using the static turbulence creating system provided inside the mixing unit, through which both gases are mixed homogeneously. The working unit is further configured to emit the cooled flue gas mixture into the flue gas passage with a homogeneous temperature of between 300°C and 425°C, which is workable by the one or more SCR catalysts and the one or more CO catalysts.

[0040] The flue gas passage is further in fluidical connection with for instance a stack to eject the flue gas into the atmosphere. Optionally, the treated flue gas could be used for any other processes, whenever applicable.

[0041] It is remarked that the higher the applied temperatures in the reduction system, the less cooling fluid needs to be added, the smaller the reduction system. The temperature needs to be chosen such that there is a balance between the design of the one or more SCR catalysts and the size of the reduction system.

[0042] In an exemplary embodiment of a reduction system to reduce one or more environmentally harmful gases in a flue gas produced by a fuelled power generator according to the present disclosure as shown in Figure 1, the reduction system (1) comprises an exhaust duct arrangement (2) for a fuelled power generator (not shown on the figure) and an ammonia injection system (3). The exhaust duct arrangement (2) comprises a flue gas passage (21), with an inlet (28) and an outlet (29), and two cooling fluid passages (22) configured to receive cooling fluid (23). The cooling fluid (23) can be blown into the respective cooling fluid passage (22) by means of a fan (not shown in figure 1) The hot flue gas produced by the fuelled power generator enters the flue gas passage (1) via the inlet (28) of the flue gas passage (21) and flows then through the flue gas passage (21) in the direction of a

mixing unit (25). The two cooling fluid passages (22) end into the flue gas passage (21), and are thus in fluidical connection with the flue gas passage (21). The flue gas passage (21) is also in fluidical connection with the mixing unit (25). The ammonia injection system (3) comprises two injectors (31), each one of these being in fluidical connection with one of the cooling fluid passages (22) and each one of these partially extending with its end part in the respective cooling fluid passage (22). Each injector (31) is in fluidical connection with a heat exchanger (32) which serves as a vaporizer to vaporize an aqueous ammonia solution to an ammonia / water vapor. An ammonia flow control unit (33) (AFCU) is provided outside the exhaust duct arrangement (2). This AFCU controls the amount of ammonia / water vapor which in operation of the reduction system (1) is directed to the injectors (31) depending on the ammonia demand. The AFCU is used to split (to control) the flow over the different injectors (31). In each of the cooling fluid passages (22), one mixer (24) is located upstream the respective injector (31) for mixing the ammonia / water vapor injected by the respective injector (31) in the respective cooling fluid passage (22) with the cooling fluid present in the respective cooling fluid passage (22). In this way, a reduction agent-cooling fluid mixture is obtained. The mixing unit (25) is configured to draw in reduction agent-cooling fluid mixture produced in each of the cooling fluid passages (22), and is further configured to draw in hot flue gas out of the flue gas passage (21). By means of a static turbulence creating system (not shown in the figure) arranged inside the mixing unit (25), the reduction agent-cooling fluid mixture is homogeneously mixed with hot flue gas, resulting in a cooled flue gas mixture which is emitted in the flue gas passage (21) with a homogeneous temperature distribution by the mixing unit (25). Downstream the mixing unit (25), an SCR catalyst (26) is located in the flue gas passage (21). This SCR catalyst (26) is able to remove NO_x present in the cooled flue gas mixture emitted by the mixing unit (25). Furthermore, a CO reduction catalyst (not shown in figure 1) can be arranged downstream the mixing unit (25), the CO reduction catalyst being able to remove CO present in the cooled flue gas mixture. This CO reduction catalyst (not shown on the figure) can be provided separately, up- or downstream of the SCR catalyst, or can form one catalyst together with the SCR catalyst (26). The SCR catalyst (26), as well as the optional CO catalyst, extend over the cross-section area of the flue gas passage (21). The cleaned flue gas mixture is then further directed to a stack (not shown on the figure) via the outlet (29) of the flue gas passage (21). The heat exchanger or vaporizer (32) is located in the flue gas passage (21) downstream the SCR catalyst (26).

[0043] In a method to reduce one or more environmentally harmful gases in flue gas produced by a fuelled powered generator, first, the hot flue gas produced by a fuelled power generator is directed to a flue gas passage which is a part of an exhaust duct arrangement.

[0044] In order to reduce the amount of NO_x in this hot flue gas, the hot flue gas is first cooled in the way as described in the following paragraphs.

[0045] First, a liquid NO_x reduction agent, such as an aqueous ammonia solution, is vaporized to a reduction agent vapor, such as an ammonia / water vapor, using one or more vaporizers, more in particular in the form of heat exchangers, which are more in particular located in the flue gas passage. This NO_x reduction agent vapor, more specifically the ammonia / water vapor, is then injected in the one or more cooling fluid passages by means of one or more injectors that are in fluidical connection with the vaporizer(s). In the one or more cooling fluid passages, cooling fluid is drawn in. This can be done by means of one or more fans that are configured to blow in cooling fluid in a respective cooling fluid passage. However, also other commonly used means could be used to let the cooling fluid enter a respective fluid passage. In order to allow the one or more injectors to inject the NO_x reduction agent vapor in the respective cooling fluid passage, these one or more injectors at least partially extend in one of the one or more cooling fluid passages. In order words, one end of each of the injectors is located in a respective one of the cooling fluid passages. The amount of NO_x reduction agent that needs to be injected in the respective cooling fluid passage is controlled by a reagent flow control unit, more in particular an ammonia flow control unit (AFCU) which is configured to control the amount of ammonia / water vapor to be injected in the respective cooling fluid passage, and is based on the ammonia demand and the amount of NO_x to be reduced in the flue gas. Thereafter, the injected NO_x reduction agent vapor and the cooling fluid in the respective cooling fluid passage are mixed using one or more mixers located in each of the one or more cooling fluid passages downstream of the respective one or more injectors, obtaining a reduction agent-cooling fluid mixture in the respective cooling fluid passage. This NO_x reduction agent-cooling fluid mixture present in the respective cooling fluid passage is then directed towards a mixing unit located in the flue gas passage. As already described above, the mixing unit comprising a static turbulence creating system, creates turbulence in the gases present inside the mixing unit, in that way homogeneously mixing the reduction agent-cooling fluid mixture with the hot flue gases, resulting in a cooled flue gas mixture. The cooled flue gas mixture obtained in that way has a homogeneous temperature, and is thereafter emitted by the mixing unit in the flue gas passage in the direction of the one or more SCR catalysts, and optionally the one or more CO reduction catalysts. There, NO_x , and optionally CO, is removed out of the cooled flue gas mixture, more in particular to a limit as defined in the emission norms, or even lower than that limit.

[0046] The treated flue gas is then finally evacuated to for instance a stack.

[0047] A NO_x reduction agent injection system accord-

ing to the present disclosure is arranged to form part of a reduction system for reducing one or more environmentally harmful gases out of a flue gas produced by a fuelled power generation according to the present disclosure.

[0048] The reduction system according to the present disclosure comprises an exhaust duct arrangement comprising a flue gas passage which is configured to receive the hot flue gas produced by the fuelled power generator, and which is configured to let the flue gas flow through it. The exhaust duct arrangement comprises one or more cooling fluid passages configured to draw in cooling fluid or let cooling fluid enter, and is configured to let the cooling fluid flow through it.

[0049] The reduction system further comprises a mixing unit located in the flue gas passage. This mixing unit comprises a static turbulence creating system which is in general configured to create a turbulence in the gases present in the mixing unit during operation, in that way homogeneously mixing the gases, resulting in a homogeneous gas mixture. The mixing unit is further configured to emit the homogeneous gas mixture in the flue gas passage with a homogeneous temperature throughout the homogeneous gas mixture;

[0050] The reduction system further comprises at least one SCR catalyst located in the flue gas passage downstream the mixing unit.

[0051] The NO_x reduction agent injection system according to the present disclosure comprises first of all one or more vaporizers for vaporizing a liquid NO_x reduction agent to a NO_x reduction agent vapor. These one or more vaporizers are configured to be located in the flue gas passage, and are more in particular in the form of heat exchangers. The NO_x reduction agent injection system further comprises one or more injectors which are fluidically connected with one of the one or more vaporizers, the one or more injectors being configured to at least partially extend into one of the one or more cooling fluid passages, and being configured to inject the NO_x reduction agent vapor in the cooling fluid present in the respective cooling fluid passage. The NO_x reduction agent injection system also comprises one or more mixers that are configured to be located in a respective one of the one or more cooling fluid passages. These one or more mixers are fitted upstream of the one or more injectors. These mixers are configured to mix the cooling fluid with the NO_x reduction agent vapor which is in operation injected in the cooling fluid present in the respective cooling fluid passage, obtaining a reduction agent-cooling fluid mixture.

[0052] To provide a cooled flue gas mixture, the mixing unit as described above is configured to draw in hot flue gas from the flue gas passage and reduction agent-cooling fluid mixture from the one or more cooling fluid passages. In the mixing unit, a static turbulence creating system is provided which is configured to create a turbulence in the reduction reaction-cooling fluid mixture and the hot exhaust gas present in the mixing unit during operation, in that way homogeneously mixing of these

gases, resulting in a homogeneous, cooled flue gas mixture. The mixing unit is further configured to emit this homogeneous, cooled flue gas mixture in the flue gas passage with a homogeneous temperature throughout the cooled flue gas mixture.

[0053] The one or more SCR catalysts located in the flue gas passage downstream the mixing unit as described above, are then configured to remove NO_x from the cooled flue gas mixture, more in particular to a limit as defined in the emission norms, or to an amount of NO_x even below that limit.

[0054] A power production plant according to the present disclosure comprises on the one hand one or more fuelled power generators and on the other hand one or more reduction systems to reduce one or more environmentally harmful gases out of flue gas produced by these one or more fuelled power generators according to the present disclosure as described above. The one or more fuelled power generators are in fluidical connection with the one or more reduction systems.

Claims

1. A reduction system to reduce one or more environmentally harmful gases out of flue gas produced by a fuelled power generator, wherein the reduction system comprises
 - an exhaust duct arrangement comprising
 - a flue gas passage configured to receive the flue gas produced by the fuelled power generator and configured to let the flue gas flow through it, and
 - one or more cooling fluid passages that are configured to draw in cooling fluid and to let cooling fluid flow through it,
 - a NO_x reduction agent injection system, in order to reduce NO_x as a harmful gas in the flue gas, comprising
 - one or more vaporizers for vaporizing a liquid NO_x reduction agent to a NO_x reduction agent vapor, wherein the vaporizers optionally are heat exchangers, and
 - one or more injectors which each are fluidically connected with one of the one or more vaporizers, wherein the one or more injectors each at least partially extend in one of the one or more cooling fluid passages, and wherein the injectors are configured to inject the NO_x reduction agent in the cooling fluid present in the respective cooling fluid passage,
 - one or more mixers located in the one or more cooling fluid passages upstream of

- the one or more injectors, and configured to mix the cooling fluid with the NO_x reduction agent, which is in operation injected by the one or more injectors in the respective cooling fluid passage, obtaining a reduction agent-cooling fluid mixture,
- a mixing unit located in the flue gas passage, the mixing unit being configured to draw in hot flue gas from the flue gas passage, and being fluidically connected with the one or more cooling fluid passages allowing reduction agent-cooling fluid mixture to be drawn in, and comprising a static turbulence creating system which is configured to create a turbulence in the hot flue gas and the reduction agent-cooling fluid present in the mixing unit during operation, in that way homogeneously mixing the reduction agent-cooling fluid mixture with the hot flue gases, resulting in a cooled flue gas mixture, and the mixing unit further being configured to emit the cooled flue gas mixture in the flue gas passage with a homogeneous temperature throughout the cooled flue gas mixture, and
- at least one selective catalytic reduction (SCR) catalyst located in the flue gas passage downstream the mixing unit, the SCR catalyst being configured to remove nitrogen oxides from the cooled flue gas mixture.
2. Reduction system according to claim 1, wherein the one or more vaporizers are located downstream the at least one SCR catalyst.
 3. Reduction system according to claim 1 or 2, wherein the reagent injection system comprises a reduction agent flow control unit to control the amount of reduction agent vapor to be directed to the one or more injectors depending on the reduction agent demand.
 4. Reduction system according to any one of claims 1 to 3, wherein the NO_x reduction agent is ammonia, and wherein the one or more vaporizers are configured to vaporize an aqueous ammonia solution to ammonia / water vapor, more in particular having a temperature of between 110 °C and 400°C.
 5. Reduction system according to claim 3 or 4, wherein the NO_x reduction agent injection system is an ammonia injection system, and wherein the NO_x reduction agent flow control unit is an ammonia flow control unit (AFCU) to control the amount of ammonia / water vapor to be directed to the one or more injectors depending on the ammonia demand.
 6. Reduction system according to any one of the preceding claims, wherein the exhaust duct arrangement comprises two cooling fluid passages.
 7. Reduction system according to any one of the preceding claims, wherein the cooling fluid is a cooling gas or ambient air or a mixture of cooling air / gas with steam or vapor or droplets of a liquid.
 8. Reduction system according to any one of the preceding claims, wherein the cooling fluid has a temperature of between 5°C and 45°C.
 9. Reduction system according to any one of the preceding claims, wherein at least one CO reducing catalyst is located in the flue gas passage separate downstream the mixing unit, located upstream or downstream of the one or more SCR catalysts, or wherein the at least one CO reducing catalyst is integrated with the one or more SCR catalysts.
 10. A method to reduce one or more environmentally harmful gases in flue gas produced by a fuelled powered generator, the method comprising the steps of
 - directing hot flue gas from the fuelled power generator to a flue gas passage of an exhaust duct arrangement and letting the hot flue gas flow through the flue gas passage;
 - entering cooling fluid in one or more cooling fluid passages of the exhaust duct arrangement and letting the cooling fluid flow through these;
 - in order to reduce NO_x as a harmful gas out of the flue gas,
 - vaporizing a liquid NO_x reduction agent to a reduction agent vapor using one or more vaporizers;
 - injecting the NO_x reduction agent vapor in cooling fluid present in the respective cooling fluid passage using one or more injectors that each extend at least partially in one of the one or more cooling fluid passages and that each are in fluidical connection with one of the one or more vaporizers;
 - mixing the injected NO_x reduction agent vapor and the cooling fluid in the respective cooling fluid passage using one or more mixers each located in one of the one or more cooling fluid passages downstream of the respective one or more injectors, obtaining a reduction agent-cooling fluid mixture in the respective cooling fluid passage;
 - directing the NO_x reduction agent-cooling fluid mixture in the respective cooling fluid passage towards a mixing unit located in the flue gas passage, the mixing unit comprising a static turbulence creating system,

- creating turbulence in the reduction agent-cooling fluid mixture and the hot flue gas present inside the mixing unit by means of the static turbulence creating system, in that way homogeneously mixing of the reduction agent-cooling fluid mixture with the hot flue gases, resulting in a cooled flue gas mixture;
 - emitting the cooled flue gas mixture with a homogeneous temperature by the mixing unit in the flue gas passage;
 - directing the cooled flue gas mixture to at least one SCR catalyst, and removing NO_x out of the cooled flue gas mixture, and
 - optionally, in order to reduce CO as a harmful gas out of the flue gas, removing CO out of the cooled flue gas mixture by means of one or more CO reduction catalysts located downstream the mixing unit, either separately downstream or upstream of the one or more SCR catalysts, either integrated with the one or more SCR catalysts.
11. A method according to claim 10, wherein the NO_x reduction agent is ammonia, and wherein the liquid NO_x reduction agent is an aqueous ammonia solution and the NO_x reduction agent vapor is ammonia / water vapor.
12. A method according to any claim 10 or 11, wherein a NO_x reduction system according to any one of claims 1 to 9 is used.
13. A NO_x reduction agent injection system for a reduction system for reducing one or more environmentally harmful gases out of a flue gas produced by a fuelled power generation, the reduction system comprising an exhaust duct arrangement which comprises
- a flue gas passage configured to draw in hot flue gas produced by the fuelled power generator and configured to allow the flue gas to flow through it;
 - one or more cooling fluid passages configured to draw in cooling fluid and configured to allow the cooling fluid flow through it;
 - a mixing unit located in the flue gas passage, the mixing unit comprising a static turbulence creating system which is configured to create a turbulence in the gases present in the mixing unit during operation, in that way homogeneously mixing the gases, resulting in a homogeneous gas mixture, and the mixing unit further being configured to emit the homogeneous gas mixture in the flue gas passage with a homogeneous temperature throughout the homogeneous gas mixture;
 - at least one SCR catalyst located in the flue gas passage downstream the mixing unit, and
- wherein the NO_x reduction agent injection system comprises
- one or more vaporizers for vaporizing a liquid NO_x reduction agent to a NO_x reduction agent vapor, the one or more vaporizers being configured to be located in the flue gas passage, and
 - one or more injectors which each are fluidically connected with one of the one or more vaporizers, the one or more injectors each being configured to at least partially extend into one of the one or more cooling fluid passages, and which are configured to inject the NO_x reduction agent vapor in the cooling fluid present in the respective cooling fluid passage,
 - one or more mixers that are configured to be located in one of the one or more cooling fluid passages upstream of the one or more injectors, and which are configured to mix the cooling fluid with the NO_x reduction agent vapor which is in operation injected in the respective cooling fluid passage, obtaining a reduction agent-cooling fluid mixture, and
- wherein
- the mixing unit is configured to draw in hot flue gas from the flue gas passage, and is fluidically connected with the one or more cooling fluid passages allowing reduction agent-cooling fluid mixture to be drawn in, and wherein the static turbulence creating system is configured to create a turbulence in the reduction agent-cooling fluid mixture and the hot flue gas present in the mixing unit during operation, in that way homogeneously mixing the reduction agent-cooling fluid mixture and the hot flue gas, resulting in a cooled flue gas mixture, and wherein the mixing unit is further configured to emit the cooled flue gas mixture in the flue gas passage with a homogeneous temperature throughout the cooled flue gas mixture, and
 - the one or more SCR catalysts are configured to remove NO_x from the cooled flue gas mixture.
14. NO_x reduction agent injection system according to claim 13 for a reduction system according to any one of claims 1 to 9.
15. Power production plant comprising one or more fuelled power generators and one or more reduction systems according to any one of claims 1 to 9, wherein each of the one or more fuelled power generators is fluidically connected with the one or more

reduction systems.

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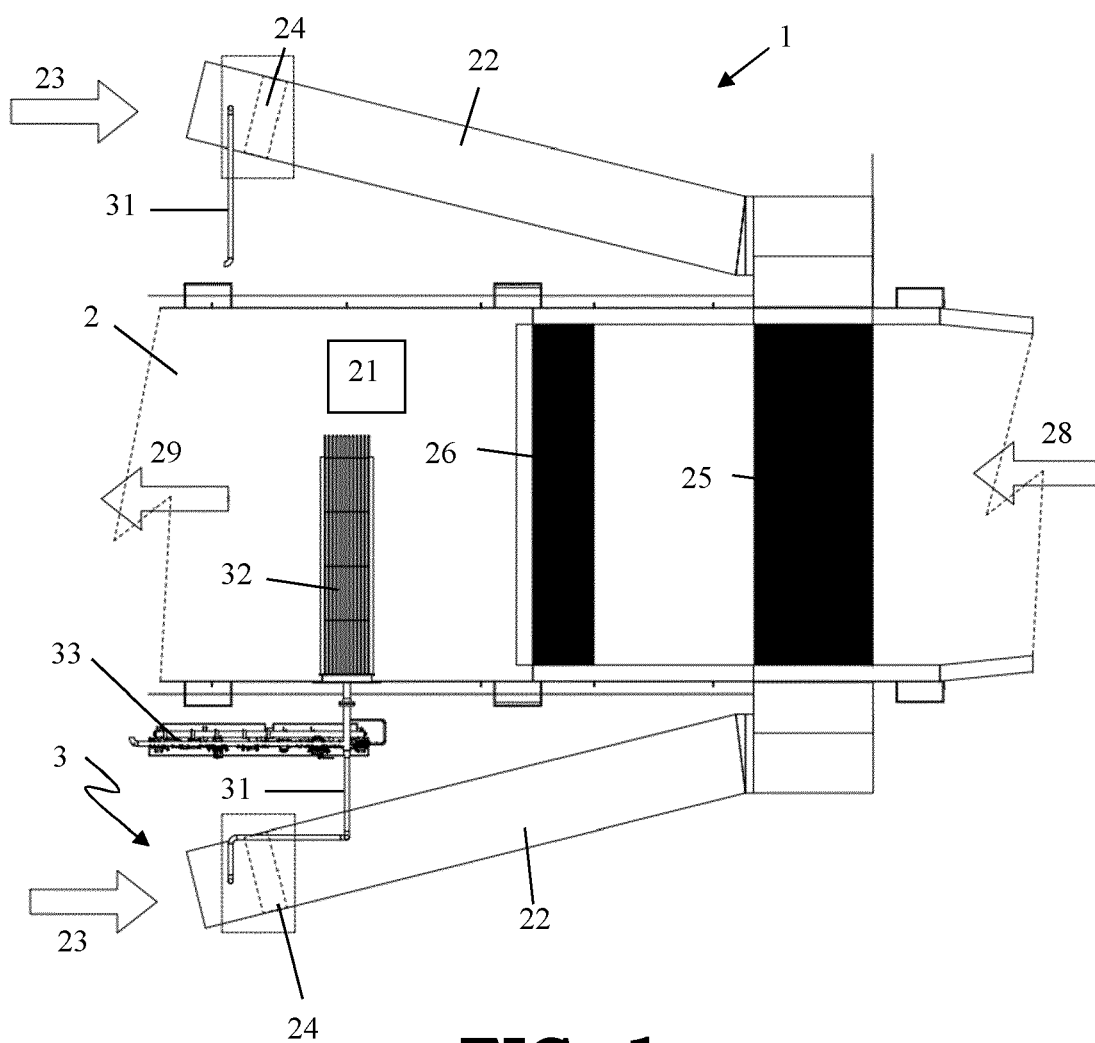


FIG. 1



EUROPEAN SEARCH REPORT

Application Number

EP 23 21 1904

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 2 554 814 A1 (GEN ELECTRIC [US]) 6 February 2013 (2013-02-06)	1, 3-5, 7, 8, 10-15	INV. F01N3/2066
Y	* paragraphs [0021], [0022], [0025];	9	
A	figure 7 *	2, 6	

Y	EP 3 135 877 A1 (GEN ELECTRIC [US]) 1 March 2017 (2017-03-01)	9	
A	* paragraphs [0028] - [0037]; figure 7 *	1, 3-5, 7, 8, 10-15	

A	EP 3 137 745 B1 (JOHNSON MATTHEY CATALYSTS GERMANY GMBH [DE]) 28 November 2018 (2018-11-28) * paragraphs [0040] - [0043]; figures 1, 2 *	1, 2, 4, 10, 11, 13, 14	

The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			F01N
Place of search			Examiner
Munich			Kolland, Ulrich
Date of completion of the search			
17 April 2024			
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 21 1904

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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17-04-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2554814 A1	06-02-2013	CN 102913311 A	06-02-2013
		EP 2554814 A1	06-02-2013
		US 2013031910 A1	07-02-2013
EP 3135877 A1	01-03-2017	CN 106481408 A	08-03-2017
		EP 3135877 A1	01-03-2017
		JP 2017048787 A	09-03-2017
		US 2017058742 A1	02-03-2017
EP 3137745 B1	28-11-2018	CN 106103927 A	09-11-2016
		DE 102015204294 A1	17-09-2015
		EP 3137745 A1	08-03-2017
		JP 2017512934 A	25-05-2017
		KR 20160130456 A	11-11-2016
		RU 2016139383 A	13-04-2018
		US 2015260071 A1	17-09-2015
		WO 2015136263 A1	17-09-2015

EPO FORM P0459

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 3529466 A [0004]