IN-SITU REGENERATION OF FILTER MEDIUM FOR IMPROVING CATALYTIC EFFICIENCY

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Provisional Application No. 63/452,947, filed March 17, 2023, which is incorporated herein by reference in its entirety for all purposes.

FIELD

[0002] The present disclosure relates generally to apparatuses, systems, and methods of cleaning a flue gas stream. More specifically, the disclosure relates to apparatuses, systems, and methods of regenerating a filter medium for use in cleaning a flue gas stream.

BACKGROUND

[0003] Coal-fired power generation plants, municipal waste incinerators, and oil refinery plants generate large amounts of flue gases that contain substantial varieties and quantities of environmental pollutants, nitrogen oxides (NOx compounds), mercury (Hg) vapor, and particulate matters (PM). In the United States, burning coal alone generates about 27 million tons of SO_2 and 45 tons of Hg each year. Thus, there is a need for improvements to methods for removing NOx compounds, sulfur oxides, mercury vapor, and fine particulate matters from industrial flue gases, such as coal-fired power plant flue gas.

SUMMARY

[0004] Catalytic filter medium or filter bags may be used to remove NOx in flue gas streams. During the selective reduction (SCR) of NOx, ammonium bisulfate (ABS, NH_4HSO_4) may be produced that covers the catalyst-active sites and may shorten the catalyst lifespan.

[0005] The present disclosure generally relates to a method for regenerating the catalytic filter medium or filter bags in-situ by removing the formed ABS and recover the catalytic performance. The method depends on NO_2 being present in the flue gas stream while it passes through the catalytic filter bag. In some examples, the method includes increasing the upstream NO_2 concentration via introducing an oxidizing agent into the flue gas stream. In certain examples, the method includes introducing

NO_2 into the flue gas stream in addition to the oxidizing agent. In some examples, the method includes mixing NO with an oxidant outside the flue gas duct to form NO_2, then injecting the mixed gas containing NO_2 into the flue gas duct upstream of the baghouse.

[0006] According to one example (“Item 1”), a method includes providing at least one filter medium; flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium; and increasing NOx removal efficiency of the at least one filter medium. The at least one filter medium may include at least one catalyst material; and ammonium bisulfate (ABS) deposits, ammonium sulfate (AS) deposits, or any combination thereof. The flue gas stream may include NOx compounds including: Nitric Oxide (NO), and Nitrogen Dioxide (NO_2). In some examples, the increasing of the NOx removal efficiency of the at least one filter medium includes increasing an upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds. In certain examples, the increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds includes: providing an NO stream; oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and introducing the additional NO_2 into the flue gas stream.

[0007] Item 2 is the method of Item 1, wherein the NO stream is oxidized prior to being introduced into the flue gas stream.

[0008] Item 3 is the method of any preceding Item, wherein the providing the NO stream includes removing at least some of the NO from the flue gas stream and selectively filtering the at least some of the NO from the flue gas stream to obtain the NO stream.

[0009] Item 4 is the method of any preceding Item, wherein the increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds further includes: introducing additional oxidizing agent into the flue gas stream.

[00010] Item 5 is the method of any preceding Item, wherein the method regenerates the at least one filter medium.

[00011] Item 6 is the method of any preceding Item, wherein oxidizing the NO stream with at least one oxidizing agent to form additional NO_2 is at a temperature of from -20 °C to 280 °C.

[00012] Item 7 is the method of any preceding Item, wherein the

at least one oxidizing agent is hydrogen peroxide (H_2O_2), ozone (O_3), hydroxyl radical, an organic peroxide, a metal peroxide, a peroxy-acid, or any combination thereof.

[00013] Item 8 is the method of any preceding Item, wherein the oxidizing the NO stream includes reacting the NO stream with an excess amount of the at least one oxidizing agent.

[00014] Item 9 is the method of any preceding Item, wherein a temperature of the flue gas stream ranges from 80 °C to 450 °C during the flowing step.

[00015] Item 10 is the method of Item 9, wherein the temperature of the flue gas stream ranges from 160 °C to 280 °C.

[00016] Item 11 is the method of any preceding Item, wherein the flue gas stream further includes Oxygen (O_2), Water (H_2O), Nitrogen (N_2), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Sulfur Trioxide (SO_3), one or more hydrocarbons, one or more particulates or any combination thereof.

[00017] Item 12 is the method of any preceding Item, wherein flowing the flue gas stream transverse to the cross-section of the at least one filter medium includes flowing the flue gas stream perpendicular to the cross-section of the at least one filter medium.

[00018] Item 13 is the method of any preceding Item, wherein the at least one filter medium is disposed within at least one filter bag, wherein the at least one filter bag is housed within at least one filter bag housing, and wherein the at least one catalyst material is in the form of catalyst particles.

[00019] Item 14 is the method of Item 13, wherein the at least one filter medium includes: a porous protective layer; and a porous catalytic layer, wherein the porous catalytic layer includes the catalyst particles.

[00020] Item 15 is the method of Item 14, wherein the porous protective layer of the at least one filter medium includes a microporous layer, wherein the microporous layer includes an expanded polytetrafluoroethylene (ePTFE) membrane.

[00021] Item 16 is the method of Item 14, wherein the porous catalytic layer of the at least one filter medium includes at least one polymeric substrate.

[00022] Item 17 is the method of Item 14, wherein the porous catalytic layer includes at least one ceramic substrate.

[00023] Item 18 is the method of Item 14, wherein the porous catalytic layer includes polytetrafluorethylene (PTFE), poly(ethylene-co-tetrafluoroethylene) (ETFE), ultra-high molecular weight polyethylene (UHMWPE),

polyparaxylylene (PPX), polylactic acid, polyimide, polyamide, polyaramid, polyphenylene sulfide, fiberglass, or any combination thereof.

[00024] Item 19 is the method of Item 14, wherein the catalyst particles are enmeshed within the porous catalytic layer.

[00025] Item 20 is the method any of Items 14 to 19, wherein the porous catalytic layer is in the form of a layered assembly including: a porous catalytic film; and at least one felt batt, wherein the at least one felt batt is positioned on at least one side of the porous catalytic film.

[00026] Item 21 is the method of Item 20, wherein the porous catalytic film includes an expanded polytetrafluoroethylene (ePTFE) membrane.

[00027] Item 22 is the method of Item 20, wherein the at least one felt batt includes: a polytetrafluoroethylene (PTFE) felt, a PTFE fleece, an expanded polytetrafluoroethylene (ePTFE) felt, an ePTFE fleece, a woven fluoropolymer staple fiber, a nonwoven fluoropolymer staple fiber, or any combination thereof.

[00028] Item 23 is the method of any preceding Item, wherein the at least one catalyst material includes at least one of: Vanadium Monoxide (VO), Vanadium Trioxide (V_2O_3), Vanadium Dioxide (VO_2), Vanadium Pentoxide (V_2O_5), Tungsten Trioxide (WO_3), Molybdenum Trioxide (MoO_3), Titanium Dioxide (TiO_2), Silicon Dioxide (SiO_2), Aluminum Trioxide (Al_2O_3), Manganese Oxide (MnO_2), zeolites, or any combination thereof.

[00029] Item 24 is the method of any preceding Item, wherein ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 99% by mass of the at least one filter medium during the providing step.

[00030] Item 25 is the method of any preceding Item, wherein, after increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 98% by mass of the at least one filter medium.

[00031] Item 26 is the method of any preceding Item, wherein the at least one oxidizing agent is O_3.

[00032] Item 27 is the method of any preceding Item, wherein the at least one oxidizing agent is H_2O_2.

[00033] Item 28 is the method of any preceding Item, wherein

the increasing of the NOx removal efficiency further includes removing at least some of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium.

[00034] Item 29 is the method of any preceding Item, further including adding ammonia (NH_3) to the flue gas stream.

[00035] Item 30 is the method of Item 29, wherein the NH_3 added has a concentration ranging from 0.0001% to 0.5% of a concentration of the flue gas stream.

[00036] Item 31 is a method including: providing at least one filter medium; flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium from an upstream side of the filter medium to a downstream side of the filter medium; and maintaining a NOx removal efficiency of the at least one filter medium in an amount of at least 50% of an initial NOx removal efficiency of the at least one filter medium by: providing an NO_2 concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NOx compounds, and controlling the NO_2 concentration, measured from the downstream side of the filter medium, to a range of from 0.0001% to 0.5% of the concentration of the flue gas stream. In some examples, the at least one filter medium includes at least one catalyst material. In some examples, the flue gas stream includes NOx compounds including: Nitric Oxide (NO), and Nitrogen Dioxide (NO_2); Sulfur Dioxide (SO_2); and Ammonia (NH_3). In some examples, providing the NO_2 concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NOx compounds includes: providing an NO stream; oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and introducing the additional NO_2 into the flue gas stream.

[00037] Item 32 is the method of any of the preceding Items, wherein the method cleans the flue gas stream.

[00038] Item 33 is the method of any of the preceding Items, wherein the at least one filter medium includes a porous catalytic fluoropolymer film having an upstream side and a downstream side, wherein the porous catalytic fluoropolymer film includes a plurality of perforations, wherein each of the plurality of perforations is a straight passageway from an entrance surface at the upstream side of the porous catalytic fluoropolymer film to an exit surface at the downstream side of the porous catalytic fluoropolymer film. In some examples, the straight passageway is

configured to enhance flow therethrough as compared to flow via the pores of the material, and the straight passageway has a diameter of 0.1 mm to 3 mm. In some examples, a percent open area of the porous catalytic fluoropolymer film is from 0.14% to 50%.

[00039] Item 34 is a system including at least one filter medium, at least one filter bag, and at least one filter bag housing. The at least one filter medium may include an upstream side; a downstream side; at least one catalyst material; and ammonium bisulfate (ABS) deposits, ammonium sulfate (AS) deposits, or any combination thereof. The at least one filter medium may be disposed within the at least one filter bag, and the at least one filter bag may be disposed within the at least one filter bag housing. In some examples, the at least one filter bag housing is configured to receive a flow of a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium from the upstream side of the at least one filter medium to the downstream side of the at least one filter medium, wherein the flue gas stream includes: NOx compounds including: Nitric Oxide (NO), and Nitrogen Dioxide (NO_2). In some examples, the system is configured to increase an NOx removal efficiency of the at least one filter medium when an upstream NO_2 concentration is increased to a range from 2% to 99% of a total concentration of the upstream NOx compounds. In some examples, increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds includes: providing an NO stream; oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and introducing the additional NO_2 into the flue gas stream.

[00039a] In an aspect, there is provided a method comprising:

providing at least one filter medium;

wherein the at least one filter medium comprises:

at least one catalyst material; and

ammonium bisulfate (ABS) deposits, ammonium sulfate (AS) deposits, or any combination thereof;

flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium,

wherein the flue gas stream comprises:

NOx compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO_2); and

increasing NOx removal efficiency of the at least one filter medium;

wherein the increasing of the NOx removal efficiency of the at least one filter medium comprises increasing an upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds,

wherein the increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds comprises:

providing an NO stream;

oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and

introducing the additional NO_2 into the flue gas stream; optionally wherein the NO stream is oxidized prior to being introduced into the flue gas stream; and optionally wherein the method regenerates the at least one filter medium.

[00039b] In another aspect, there is provided a method comprising:

providing at least one filter medium

wherein the at least one filter medium comprises at least one catalyst material;

flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium from an upstream side of the filter medium to a downstream side of the filter medium;

wherein the flue gas stream comprises:

NOx compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO_2);

Sulfur Dioxide (SO_2); and

Ammonia (NH_3);

maintaining a NOx removal efficiency of the at least one filter medium in an amount of at least 50% of an initial NOx removal efficiency of the at least one filter medium by:

providing an NO_2 concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NOx compounds, wherein providing the NO_2 concentration, measured

from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NOx compounds comprises:

providing an NO stream;

oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and

introducing the additional NO_2 into the flue gas stream; and

controlling the NO_2 concentration, measured from the downstream side of the filter medium, to a range of from 0.0001% to 0.5% of the concentration of the flue gas stream.

[00039c] In another aspect, there is provided a system comprising:

at least one filter medium,

wherein the at least one filter medium comprises:

an upstream side;

a downstream side;

at least one catalyst material; and

ammonium bisulfate (ABS) deposits, ammonium sulfate (AS) deposits, or any combination thereof;

at least one filter bag,

wherein the at least one filter medium is disposed within the at least one filter bag; and

at least one filter bag housing,

wherein the at least one filter bag is disposed within the at least one filter bag housing;

wherein the at least one filter bag housing is configured to receive a flow of a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium from the upstream side of the at least one filter medium to the downstream side of the at least one filter medium,

wherein the flue gas stream comprises:

NOx compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO_2); and

wherein the system is configured to increase an NOx removal efficiency of the at least one filter medium when an upstream NO_2 concentration is increased to a range from 2% to 99% of a total concentration of the upstream NOx compounds,

wherein increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds comprises:

providing an NO stream;

oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and

introducing the additional NO_2 into the flue gas stream.

[00040] The foregoing Items are just that, and should not be read to limit or otherwise narrow the scope of any of the inventive concepts otherwise provided by the instant disclosure. While multiple examples are disclosed, still other examples will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative examples. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature rather than restrictive in nature.

BRIEF DESCRIPTION OF THE DRAWINGS

[00041] The accompanying drawings are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of this specification, illustrate embodiments, and together with the description serve to explain

WHAT IS CLAIMED IS:

1. A method comprising:

providing at least one filter medium;

wherein the at least one filter medium comprises:

at least one catalyst material; and

ammonium bisulfate (ABS) deposits, ammonium sulfate (AS) deposits, or any combination thereof;

flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium,

wherein the flue gas stream comprises:

NOx compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO_2); and

increasing NOx removal efficiency of the at least one filter medium;

wherein the increasing of the NOx removal efficiency of the at least one filter medium comprises increasing an upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds,

wherein the increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds comprises:

providing an NO stream;

oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and

introducing the additional NO_2 into the flue gas stream; optionally wherein the NO stream is oxidized prior to being introduced into the flue gas stream; and optionally wherein the method regenerates the at least one filter medium.

2. The method of claim 1, wherein the providing the NO stream comprises removing at least some of the NO from the flue gas stream and selectively filtering the at least some of the NO from the flue gas stream to obtain the NO stream, and optionally wherein increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds further comprises: introducing additional oxidizing agent into the flue gas stream.

3. The method of claim 1 or 2, wherein oxidizing the NO stream with at least one oxidizing agent to form additional NO_2 is at a temperature of from -20 °C to 280 °C, optionally wherein the oxidizing the NO stream comprises reacting the NO stream with an excess amount of the at least one oxidizing agent, and optionally wherein the at least one oxidizing agent is hydrogen peroxide (H_2O_2), ozone (O_3), hydroxyl radical, an organic peroxide, a metal peroxide, a peroxy-acid, or any combination thereof.

4. The method of any one of claims 1 to 3, wherein a temperature of the flue gas stream ranges from 80 °C to 450 °C during the flowing step, optionally wherein the temperature of the flue gas stream ranges from 160 °C to 280 °C.

5. The method of any one of claims 1 to 4, wherein the flue gas stream further comprises Oxygen (O_2), Water (H_2O), Nitrogen (N_2), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Sulfur Trioxide (SO_3), one or more hydrocarbons, one or more particulates or any combination thereof, optionally wherein flowing the flue gas stream transverse to the cross-section of the at least one filter medium comprises flowing the flue gas stream perpendicular to the cross-section of the at least one filter medium.

6. The method of any one of claims 1 to 5, wherein the at least one filter medium is disposed within at least one filter bag, wherein the at least one filter bag is housed within at least one filter bag housing, and wherein the at least one catalyst material is in the form of catalyst particles, optionally wherein the at least one filter medium comprises:

a porous protective layer; and

a porous catalytic layer, wherein the porous catalytic layer comprises the catalyst particles.

7. The method of claim 6, wherein the porous protective layer of the at least one filter medium comprises a microporous layer, wherein the microporous layer comprises an expanded polytetrafluoroethylene (ePTFE) membrane, optionally wherein the porous catalytic layer of the at least one filter medium comprises at least one polymeric substrate or wherein the porous catalytic layer comprises at least one ceramic substrate.

8. The method of claim 6, wherein the porous catalytic layer comprises polytetrafluorethylene (PTFE), poly(ethylene-co-tetrafluoroethylene) (ETFE), ultra-high molecular weight polyethylene (UHMWPE), polyparaxylylene (PPX), polylactic acid, polyimide, polyamide, polyaramid, polyphenylene sulfide, fiberglass, or any combination thereof, optionally wherein the catalyst particles are enmeshed within the porous catalytic layer.

9. The method of claim 6, wherein the porous catalytic layer is in the form of a layered assembly comprising:

a porous catalytic film; and

at least one felt batt, wherein the at least one felt batt is positioned on at least one side of the porous catalytic film;

optionally wherein the porous catalytic film comprises an expanded polytetrafluoroethylene (ePTFE) membrane, and optionally wherein the at least one felt batt comprises: a polytetrafluoroethylene (PTFE) felt, a PTFE fleece, an expanded polytetrafluoroethylene (ePTFE) felt, an ePTFE fleece, a woven fluoropolymer staple fiber, a nonwoven fluoropolymer staple fiber, or any combination thereof.

10. The method of any one of claims 1 to 9, wherein the at least one catalyst material comprises at least one of: Vanadium Monoxide (VO), Vanadium Trioxide (V_2O_3), Vanadium Dioxide (VO_2), Vanadium Pentoxide (V_2O_5), Tungsten Trioxide (WO_3), Molybdenum Trioxide (MoO_3), Titanium Dioxide (TiO_2), Silicon Dioxide (SiO_2), Aluminum Trioxide (Al_2O_3), Manganese Oxide (MnO_2), zeolites, or any combination thereof, optionally wherein the at least one oxidizing agent is O_3 or H_2O_2.

11. The method of any one of claims 1 to 10, wherein ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 99% by mass of the at least one filter medium during the providing step, optionally wherein after increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 98% by mass of the at least one filter medium.

12. The method of any one of claims 1 to 11, wherein the increasing of the NOx removal efficiency further comprises removing at least some of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium, optionally further comprising adding ammonia (NH_3) to the flue gas stream, optionally wherein the NH_3 added has a concentration ranging from 0.0001% to 0.5% of a concentration of the flue gas stream.

13. A method comprising:

providing at least one filter medium

wherein the at least one filter medium comprises at least one catalyst material;

flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium from an upstream side of the filter medium to a downstream side of the filter medium;

wherein the flue gas stream comprises:

NOx compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO_2);

Sulfur Dioxide (SO_2); and

Ammonia (NH_3);

maintaining a NOx removal efficiency of the at least one filter medium in an amount of at least 50% of an initial NOx removal efficiency of the at least one filter medium by:

providing an NO_2 concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NOx compounds, wherein providing the NO_2 concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NOx compounds comprises:

providing an NO stream;

oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and

introducing the additional NO_2 into the flue gas stream; and

controlling the NO_2 concentration, measured from the downstream side of the filter medium, to a range of from 0.0001% to 0.5% of the concentration of the flue gas stream.

14. The method of any of the preceding claims, wherein the at least one filter medium comprises:

a porous catalytic fluoropolymer film having an upstream side and a downstream side,

wherein the porous catalytic fluoropolymer film comprises a plurality of perforations,

wherein each of the plurality of perforations is a straight passageway from an entrance surface at the upstream side of the porous catalytic fluoropolymer film to an exit surface at the downstream side of the porous catalytic fluoropolymer film,

i) wherein the straight passageway is configured to enhance flow therethrough as compared to flow via the pores of the material, and

ii) wherein the straight passageway has a diameter of 0.1 mm to 3 mm;

wherein a percent open area of the porous catalytic fluoropolymer film is from 0.14% to 50%.

15. A system comprising:

at least one filter medium,

wherein the at least one filter medium comprises:

an upstream side;

a downstream side;

at least one catalyst material; and

ammonium bisulfate (ABS) deposits, ammonium sulfate (AS) deposits, or any combination thereof;

at least one filter bag,

wherein the at least one filter medium is disposed within the at least one filter bag; and

at least one filter bag housing,

wherein the at least one filter bag is disposed within the at least one filter bag housing;

wherein the at least one filter bag housing is configured to receive a flow of a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium from the upstream side of the at least one filter medium to the downstream side of the at least one filter medium,

wherein the flue gas stream comprises:

NOx compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO_2); and

wherein the system is configured to increase an NOx removal efficiency of the at least one filter medium when an upstream NO_2 concentration is increased to a range from 2% to 99% of a total concentration of the upstream NOx compounds,

wherein increasing the upstream NO_2 concentration to a range from 2% to 99% of a total concentration of the upstream NOx compounds comprises:

providing an NO stream;

oxidizing the NO stream with at least one oxidizing agent to form additional NO_2, and

introducing the additional NO_2 into the flue gas stream.