

IMPROVING CATALYTIC EFFICIENCY OF FLUE GAS FILTRATION**FIELD**

[1] The present disclosure relates to a filter medium, methods of regenerating at least one filter medium, and methods of cleaning a flue gas stream.

BACKGROUND

[2] 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 (NO_x compounds), mercury (Hg) vapor, and particulate matters (PM). In the United States, burning coal alone generates about 27 million tons of SO₂ and 45 tons of Hg each year. Thus, there is a need for improvements to methods for removing NO_x compounds, sulfur oxides, mercury vapor, and fine particulate matters from industrial flue gases, such as coal-fired power plant flue gas.

SUMMARY

[3] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

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

wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

wherein the method regenerates the at least one filter medium.

[4] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

controlling the NO₂ 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;

wherein the method cleans the flue gas stream.

[5] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the system is configured to increase a NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, and wherein the upstream NO₂ concentration

is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds by introducing additional NO₂ into the flue gas stream.

[6] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a NO_x removal efficiency of the at least one filter medium in an amount of at least 70% of an initial NO_x efficiency by:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

controlling NO₂ 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

wherein the method cleans the flue gas stream.

[7] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

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

wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream;

wherein the method regenerates the at least one filter medium.

[8] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of

a total concentration of the NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream; and

controlling the NO₂ 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;

wherein the method cleans the flue gas stream.

[9] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the system is configured to increase an NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, and wherein the upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds by introducing at least one oxidizing agent into the flue gas stream.

[10] Some aspects of the present disclosure relate to 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a NO_x removal efficiency of the at least one filter medium in an amount of at least 70% of an initial NO_x efficiency by:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream; and

controlling NO₂ 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;

wherein the method cleans the flue gas stream.

DRAWINGS

[11] Some embodiments of the disclosure are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the embodiments shown are by way of example and for purposes of illustrative discussion of embodiments of the disclosure. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the disclosure may be practiced.

[12] Figures 1A-1D depict embodiments of an exemplary filter medium and according to the present disclosure.

[13] Figure 2 depicts an exemplary NO_x removal efficiency after in-situ flow-through regeneration by NO and NO₂ gas mixture on an exemplary filter medium.

[14] Figure 3 depicts an exemplary relative NO_x removal efficiency after in-situ flow-through regeneration by NO and NO₂ gas mixture on an exemplary filter medium.

[15] Figure 4 depicts exemplary NO_x concentrations, measured from a downstream side of an exemplary filter medium, during the in-situ flow through regeneration by an NO and NO₂ mixture.

[16] Figure 5 depicts an exemplary relative NO_x removal efficiency after in-situ flow-through regeneration by NO, NO₂ and NH₃ gas mixture on an exemplary filter medium.

[17] Figure 6 depicts an exemplary NO_x concentration, measured from a downstream side of an exemplar filter medium, during the in-situ flow through regeneration by a mixture comprising NO, NO₂, and NH₃.

[18] Figure 7 depicts an exemplary NO_x removal efficiency after in-situ flow-by regeneration on an exemplary filter medium by a mixture comprising NO, NO₂, and NH₃.

[19] Figure 8 depicts an exemplary NO_x removal efficiency after in-situ flow-through regeneration on exemplary filter bags by a mixture comprising NO, NO₂, and NH₃.

[20] Figure 9 depicts an example of “long term” NO_x removal efficiency with SO₂ and excess NO₂ in the downstream.

[21] Figure 10 depicts an example of “long term” NO_x removal efficiency with SO₂ but without excess NO₂ in the downstream.

[22] Figure 11 depicts an example of downstream NO₂ concentration in an exemplary “long term” NO_x removal efficiency measurement.

[23] Figure 12 depicts an example of NO_x removal efficiency and downstream NO₂ concentration before, during and after in-situ flow-through regeneration by NO, NO₂, and NH₃ mixture with exposure to SO₂.

[24] Figure 13 depicts an example of NO_x removal efficiency before, during and after in-situ flow-through regeneration (148 hours) by NO, NO₂, and NH₃ mixture with exposure to SO₂.

[25] Figure 14 depicts NO_x removal efficiency with intermittent in-situ flow-through regeneration by an exemplary NO, NO₂, and NH₃ mixture with exposure to SO₂.

[26] Figure 15 depicts an exemplary NO and NO₂ concentration change with upon injection of 1 wt% hydrogen peroxide (H₂O₂) into a simulated flue gas stream comprising SO₂ and NO.

[27] Figure 16 depicts an exemplary NO to NO₂ percentage conversion upon injection of 1 wt% H₂O₂ injection into a simulated flue gas stream comprising SO₂ and NO at different temperatures.

[28] Figure 17 depicts an exemplary NO to NO₂ percentage conversion upon injection of 0.3 wt% H₂O₂ injection into a simulated flue gas stream comprising SO₂ and NO at different temperatures.

DETAILED DESCRIPTION

[29] Among those benefits and improvements that have been disclosed, other objects and advantages of this disclosure will become apparent from the following description taken in conjunction with the accompanying figures. Detailed embodiments of the present disclosure are disclosed herein; however, it is to be understood that the disclosed embodiments are merely illustrative of the disclosure that may be embodied in various forms. In addition, each of the examples given regarding the various embodiments of the disclosure which are intended to be illustrative, and not restrictive.

[30] Throughout the specification and claims, the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise. The phrases “in one embodiment,” “in an embodiment,” and “in some embodiments” as used herein do not necessarily refer to the same embodiment(s), though it may. Furthermore, the phrases “in another embodiment” and “in some other embodiments” as used herein do not necessarily refer to a different embodiment, although it may. All embodiments of the disclosure are intended to be combinable without departing from the scope or spirit of the disclosure.

[31] As used herein, the term “based on” is not exclusive and allows for being based on additional factors not described, unless the context clearly dictates otherwise. In addition, throughout the specification, the meaning of “a,” “an,” and “the” include plural references. The meaning of “in” includes “in” and “on.”

[32] All prior patents, publications, and test methods referenced herein are incorporated by reference in their entireties.

[33] As used herein, the term “flue gas stream” refers to a gaseous mixture that comprises at least one byproduct of a combustion process (such as, but not limited to, a coal combustion process). In some embodiments, a flue gas stream may include at least one gas in an elevated concentration relative to a concentration resulting from the combustion process. For instance, in one non-limiting example, a flue gas stream may be subjected to a “scrubbing” process during which water vapor may be added to the flue gas. Accordingly, in some such embodiments, the flue gas stream may include water vapor in an elevated concentration relative to the initial water vapor concentration due to combustion. Similarly, in some embodiments, a flue gas stream may include at least one gas in a lesser concentration relative to an initial concentration of the at least one gas output from the combustion process. This may occur, for example, by removing at least a portion

at least one gas after combustion. In some embodiments, a flue gas may take the form of a gaseous mixture that is a combination of byproducts of multiple combustion processes.

[34] As used herein, the term “flow through” means that a flue gas stream is flowed transverse to a cross section of the at least one filter medium, such that the flue gas stream passes through a cross section of the at least one filter medium. In some embodiments of a “flow through” configuration, the flue gas stream is flowed perpendicular to a cross-section of the at least one filter medium.

[35] As used herein, the term “flow by” means that the flue gas stream is not flowed transverse to a cross section of the at least one filter medium, such that the flue gas does not pass through the cross section of the at least one filter medium. In some embodiments of a “flow by” configuration, the flue gas stream is flowed parallel to a cross-section of the at least one filter medium.

[36] As used herein “upstream” refers to a location of a flue gas stream before entering a filter medium. In the “flow through” context, “upstream” may refer to the location of a flue gas stream before entering a cross section of a filter medium. In the “flow by” context, “upstream” may refer to the location of a flue gas stream before entering an enclosure (e.g., a housing, a filter bag, or other suitable enclosure described herein) that contains a filter medium.

[37] As used herein “downstream” refers to a location of a flue gas stream after exiting a filter medium. In the “flow through” context, “downstream” may refer to the location of a flue gas stream after exiting a cross section of a filter medium. In the “flow by” context, “downstream” may refer to the location of a flue gas stream after exiting an enclosure (e.g., a housing, a filter bag, or other suitable enclosure described herein) that contains a filter medium.

[38] As used herein, the term “NO_x compound” refers to any oxide of nitrogen. In some non-limiting embodiments, “NO_x compound” may specifically refer to gaseous oxides of nitrogen that are known environmental pollutants.

[39] As used herein, the term “catalytic composite article” set forth in the Examples refers to any material that includes a combination of at least one catalyst material and at least one additional material according to any embodiment described herein. The additional material is not limited to any particular type of material and may be, for example, a membrane, a felt batt, a ceramic substrate (including but not limited to a ceramic candle), a honeycomb substrate, a monolith substrate, or any combination thereof. The catalytic composite article may, in some non-limiting examples, be a porous catalytic film.

[40] Some embodiments of the present disclosure relate to a method of regenerating at least one filter medium. As used herein, “regenerating at least one filter medium” means that, after regeneration, the at least one filter medium has a higher removal efficiency of at least one component of the flue gas stream as compared to a removal efficiency of the at least one component of the flue gas stream, prior to regeneration. For example, in some non-limiting embodiments, after regeneration, the at least one filter medium may have a higher removal efficiency of NO, NO₂, or combination thereof, as compared to a removal efficiency of the at least one component of the NO, NO₂, or combination thereof, prior to regeneration.

[41] In some embodiments, the at least one filter medium comprises at least one catalyst material. In some embodiments, the at least one catalyst material comprises at least one of: Vanadium Monoxide (VO), Vanadium Trioxide (V₂O₃), Vanadium Dioxide (VO₂), Vanadium Pentoxide (V₂O₅), Tungsten Trioxide (WO₃), Molybdenum Trioxide (MoO₃), Titanium Dioxide (TiO₂), Silicon Dioxide (SiO₂), Aluminum Trioxide (Al₂O₃), Manganese Oxide (MnO₂), zeolites,

or any combination thereof. In some embodiments, the at least one catalyst material is in the form of catalyst particles.

[42] In some embodiments, the at least one filter medium comprises an upstream side and a downstream side. In some embodiments, the at least one filter medium is disposed within at least one filter bag. In some embodiments, a plurality of filter mediums is disposed within a single filter bag. In some embodiments, the at least one filter bag is housed within at least one filter bag housing. In some embodiments, a plurality of filter bags is disposed within a single filter bag housing.

[43] In some embodiments, the one filter medium comprises a porous protective layer and a porous catalytic layer. In some embodiments, the porous catalytic layer comprises at least one catalyst material. In some embodiments, the at least one catalyst material is disposed on the porous catalytic layer. In some embodiments, the at least one catalyst material is within (e.g., embedded within) the porous catalytic layer.

[44] In some embodiments, the porous protective layer comprises a microporous layer. In some embodiments, the microporous layer comprises an expanded polytetrafluoroethylene (ePTFE) membrane.

[45] In some embodiments, the at least one catalyst material is adhered to the filter medium by at least one adhesive. In some embodiments, the at least one catalyst material is adhered to the porous catalytic layer by at least one adhesive. In some exemplary embodiments, the at least one filter medium is in the form of a filter bag, such that the adherence of the at least one catalyst material to the porous catalytic layer by the at least one adhesive form a coated filter bag. In some

embodiments, the at least one catalyst material is in the form of catalyst particles, such that the coated filter bag is coated with the catalyst particles.

[46] In some embodiments, the at least one adhesive is chosen from polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), high molecular weight polyethylene (HMWPE), high molecular weight polypropylene (HMWPP), perfluoroalkoxy alkane (PFA), polyvinylidene fluoride (PVDF), vinylidene fluoride (THV), chlorofluoroethylene (CFE), or any combination thereof. In some embodiments, the at least one adhesive is selected from the group consisting of polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), high molecular weight polyethylene (HMWPE), high molecular weight polypropylene (HMWPP), perfluoroalkoxy alkane (PFA), polyvinylidene fluoride (PVDF), vinylidene fluoride (THV), chlorofluoroethylene (CFE), and any combination thereof.

[47] In some embodiments, the porous catalytic layer comprises at least one polymeric substrate. In some embodiments, the at least one polymeric substrate comprises a least one of: polytetrafluoroethylene, poly(ethylene-co-tetrafluoroethylene), ultra-high molecular weight polyethylene, polyparaxylylene, polylactic acid, polyimide, polyamide, polyaramid, polyphenylene sulfide, fiberglass, or any combination thereof. In some embodiments, the at least one polymeric substrate is selected from the group consisting of: polytetrafluoroethylene, poly(ethylene-co-tetrafluoroethylene), ultra-high molecular weight polyethylene, polyparaxylylene, polylactic acid, polyimide, polyamide, polyaramid, polyphenylene sulfide, fiberglass, and any combination thereof.

[48] In some embodiments, the porous catalytic layer includes at least one ceramic substrate. In some embodiments, the at least one ceramic substrate is in the form of a ceramic candle described

herein. In some embodiments, the one ceramic substrate comprises ceramic fibers. In some embodiments, the ceramic fibers comprise alkali metal silicates, alkaline earth metal silicates, aluminosilicates, or any combination thereof.

[49] In some embodiments, the porous catalytic layer is in the form of a layered assembly comprising a porous catalytic film and one or more felt batts. In some embodiments, the one or more felt batts are positioned on at least one side of the porous catalytic film. In some embodiments, the porous catalytic film comprises the at least one catalyst material. In some embodiments, the at least one catalyst material is disposed on the porous catalytic film. In some embodiments, the at least one catalyst material is within (e.g., embedded within) the porous catalytic film.

[50] In some embodiments, the one or more felt batts comprise at least one of: 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. In some embodiments, the one or more felt batts are selected from the group consisting of: 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, and any combination thereof.

[51] In some embodiments, the porous catalytic film comprises a membrane. In some embodiments, the porous catalytic film comprises a polymer membrane. In some embodiments, the porous catalytic film comprises a fluoropolymer membrane and may be referred to as a porous catalytic fluoropolymer film. In some embodiments, the porous catalytic film comprises an expanded polytetrafluoroethylene (ePTFE) membrane.

[52] In some embodiments, the porous catalytic film comprises catalyst particles enmeshed within the ePTFE membrane. In some embodiments, the ePTFE membrane has a microstructure that includes nodes, fibrils, or any combination thereof. In some embodiments, the catalyst particles may be enmeshed into the microstructure. In some embodiments, the catalyst particles may be enmeshed into the nodes. In some embodiments, the catalyst particles may be enmeshed into the fibrils. In some embodiments, the catalyst particles may be enmeshed into the nodes and fibrils.

[53] In some embodiments, the at least one filter medium is in the form of a ceramic candle. In some embodiments, the ceramic candle comprises at least one ceramic material. In some embodiments, the least one ceramic material is chosen from: silica-aluminate, calcium-magnesium-silicate, calcium-silicate fibers, or any combination thereof. In some embodiments, catalyst particles form a coating on the at least one ceramic material.

[54] In some embodiments, the at least one filter medium may comprise any material configured to capture at least one of solid particulates, liquid aerosols, or any combination thereof from a flue gas stream. In some embodiments, the at least one filter medium is in the form of at least one of: a filter bag, a honeycomb, a monolith or any combination thereof.

[55] In some embodiments, the at least filter medium comprises ammonium bisulfate (ABS) deposits, ammonium sulfate (AS) deposits, or any combination thereof. In some embodiments, ABS deposits are disposed on the at least one catalyst material of the at least one filter medium. In some embodiments, ABS deposits are disposed within the at least one catalyst material of the at least one filter medium. In some embodiments, at least some of the ABS deposits, AS deposits, or any combination thereof may be removed, so as to increase a removal efficiency (e.g., NO_x removal efficiency) of the at least one filter medium, as described in further detail herein, infra.

[56] In some embodiments, the ABS deposits are present in a concentration ranging from 0.01% to 99% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 0.1% to 99% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 1% to 99% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 10% to 99% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 25% to 99% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 50% to 99% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 75% to 99% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 95% to 99% by mass of the at least one filter medium during the providing step.

[57] In some embodiments, the ABS deposits are present in a concentration ranging from 0.01% to 95% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 0.01% to 75% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 0.01% to 50% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 0.01% to 25% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 0.01% to 10% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS

deposits are present in a concentration ranging from 0.01% to 1% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 0.01% to 0.1% by mass of the at least one filter medium during the providing step.

[58] In some embodiments, the ABS deposits are present in a concentration ranging from 0.1% to 95% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 1% to 75% by mass of the at least one filter medium during the providing step. In some embodiments, the ABS deposits are present in a concentration ranging from 10% to 50% by mass of the at least one filter medium during the providing step.

[59] In some embodiments, the method of regenerating at least one filter medium comprises flowing a flue gas stream through the at least one filter medium (i.e., 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. In some embodiments, the flue gas stream is flowed from an upstream side to a downstream side of the at least one filter medium. In some embodiments, the flue gas stream is flowed perpendicular to a cross-section of the at least one filter medium.

[60] In some embodiments, the method of regenerating at least one filter medium comprises flowing a flue gas stream by the at least one filter medium (i.e., non-transverse to a cross-section of the at least one filter medium), such that the flue gas stream does not pass through the cross section of the at least one filter medium. In some embodiments, the flue gas stream is flowed parallel to a cross-section of the at least one filter medium.

[61] In some embodiments, the temperature of the flue gas stream ranges from 160 °C to 280 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges

from 175 °C to 280 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges from 200 °C to 280 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges from 225 °C to 280 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges from 250 °C to 280 °C during the flowing step.

[62] In some embodiments, the temperature of the flue gas stream ranges from 160 °C to 250 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges from 160 °C to 225 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges from 160 °C to 200 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges from 160 °C to 175 °C during the flowing step.

[63] In some embodiments, the temperature of the flue gas stream ranges from 175 °C to 250 °C during the flowing step. In some embodiments, the temperature of the flue gas stream ranges from 200 °C to 225 °C during the flowing step.

[64] In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 170 °C to 450 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 200 °C to 450 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 250 °C to 450 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 300 °C to

450 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 350 °C to 450 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 400 °C to 450 °C during the flowing step.

[65] In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 170 °C to 400 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 170 °C to 350 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 170 °C to 300 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 170 °C to 250 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 170 °C to 200 °C during the flowing step.

[66] In some embodiments, such as embodiments where the at least one filter medium is in the form of a or comprises ceramic substrate (e.g., a ceramic candle), the temperature of the flue gas stream ranges from 200 °C to 400 °C during the flowing step. In some embodiments, such as embodiments where the at least one filter medium is in the form of or comprises a ceramic substrate

(e.g., a ceramic candle), the temperature of the flue gas stream ranges from 250 °C to 350 °C during the flowing step.

[67] In some embodiments, the flue gas stream comprises NO_x compounds. In some embodiments, the NO_x compounds comprise Nitric Oxide (NO) and Nitrogen Dioxide (NO₂). In some embodiments, the flue gas stream further comprises at least one of Oxygen (O₂), Water (H₂O), Nitrogen (N₂), Carbon Monoxide (CO), Sulfur Dioxide (SO₂), Sulfur Trioxide (SO₃), one or more hydrocarbons, or any combination thereof.

[68] In some embodiments, the method of regenerating at least one filter medium comprises increasing NO_x removal efficiency of the at least one filter medium. In some embodiments, this increase in NO_x removal efficiency may occur as a result of removing ABS deposits, AS deposits, or any combination thereof.

[69] In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 2% to 99% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 5% to 99% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 10% to 99% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 25% to 99% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 50% to 99% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x

removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 75% to 99% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 95% to 99% of a total concentration of the NO_x compounds.

[70] In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 2% to 95% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 2% to 75% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 2% to 50% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 2% to 25% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 2% to 10% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 2% to 5% of a total concentration of the NO_x compounds.

[71] In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 5% to 95% of a total concentration of the NO_x compounds. In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 10% to 75% of a total concentration of the NO_x compounds. In some embodiments, the

increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing NO₂ concentration to a range from 25% to 50% of a total concentration of the NO_x compounds.

[72] In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream.

[73] In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 50 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.01 wt% to 50 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.1 wt% to 50 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 1 wt% to 50 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 10 wt% to 50 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 20 wt% to 50 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 30 wt% to 50 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 40 wt% to 50 wt% based on a total weight of the flue gas stream.

[74] In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 40 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 30 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 20 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 10 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 1 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 0.1 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.001 wt% to 0.01 wt% based on a total weight of the flue gas stream.

[75] In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.01 wt% to 40 wt% based on a total weight of the flue gas stream. In some embodiments, the concentration of NO₂ is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 0.1 wt% to 30 wt% based on a total weight of the flue gas stream. In some embodiments, the

concentration of NO_2 is increased by introducing at least one oxidizing agent to the flue gas stream in an amount ranging from 1 wt% to 20 wt% based on a total weight of the flue gas stream.

[76] In some embodiments, the at least one oxidizing agent comprises an organic peroxide, a metal peroxide, a peroxy-acid, or any combination thereof.

[77] Examples of at least one organic peroxide that may be suitable for some embodiments of the present disclosure include, but are not limited to, acetyl acetone peroxide, acetyl benzoyl peroxide, tert-butyl hydroperoxide, di-(1-naphthoyl)peroxide, diacetyl peroxide, ethyl hydroperoxide, methyl ethyl ketone peroxide, methyl isobutyl ketone peroxide, or any combination thereof. Examples of at least one metal peroxide that may be suitable for some embodiments of the present disclosure include but are not limited to barium peroxide (BaO_2), sodium peroxide (Na_2O_2), or any combination thereof.

[78] Examples of at least one peroxy-acid that may be suitable for some embodiments of the present disclosure include, but are not limited to, peroxymonosulfuric acid (H_2SO_5), peroxyntiric acid (HNO_4), peroxymonophosphoric acid (H_3PO_5), or any combination thereof.

[79] Further examples of at least one oxidizing agent that may be suitable for some embodiments of the present disclosure include, but are not limited to, sodium percarbonate ($\text{Na}_2\text{H}_3\text{CO}_6$), sodium perborate ($\text{Na}_2\text{H}_4\text{B}_2\text{O}_8$), potassium persulfate ($\text{K}_2\text{S}_2\text{O}_8$) potassium permanganate (KMnO_4) sodium hypochlorite (NaClO), calcium hypochlorite ($\text{Ca}(\text{ClO})$), chlorine dioxide (ClO_2) potassium chlorate (KClO_3), sodium chlorate (NaClO_3), magnesium chlorate ($\text{Mg}(\text{ClO}_3)_2$) ammonium perchlorate (NH_4ClO_4), perchloric acid (HClO_4), potassium perchlorate (KClO_4), sodium perchlorate (NaClO_4), sodium chlorite (NaClO_2), lithium hypochlorite (LiOCl), calcium hypochlorite $\text{Ca}(\text{OCl})_2$, barium hypochlorite $\text{Ba}(\text{ClO})_2$, sodium hypochlorite (NaClO), sodium bismuthate (NaBiO_3), or any combination thereof.

[80] In some embodiments, the at least one oxidizing agent is chosen from: hydrogen peroxide (H_2O_2), ozone (O_3), hydroxyl radical or any combination thereof. In some embodiments, the at least one oxidizing agent is selected from the group consisting of: H_2O_2 , O_3 , hydroxyl radical, and any combination thereof.

[81] In some embodiments, the at least one oxidizing agent comprises, consists of, or consists essentially of H_2O_2 .

[82] In some embodiments, the H_2O_2 is introduced into the flue gas stream in a sufficient amount so as to oxidize at least some of the NO in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is an amount sufficient to oxidize at least 10% of the NO concentration in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is an amount sufficient to oxidize at least 20% of the NO concentration in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is an amount sufficient to oxidize at least 30% of the NO concentration in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is an amount sufficient to oxidize at least 40% of the NO concentration in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is an amount sufficient to oxidize at least 50% of the NO concentration in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is an amount sufficient to oxidize at least 60% of the NO concentration in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is an amount sufficient to oxidize at least 70% of the NO concentration in the flue gas stream to NO_2 . In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is

an amount sufficient to oxidize at least 80% of the NO concentration in the flue gas stream to NO₂.

In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize at least 90% of the NO concentration in the flue gas stream to NO₂.

In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize at least 95% of the NO concentration in the flue gas stream to NO₂.

In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize at least all of the NO concentration in the flue gas stream to NO₂.

[83] In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 10% to 90% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 20% to 90% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 30% to 90% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 40% to 90% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 50% to 90% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 60% to 90% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 70% to 90% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced

into the flue gas stream is an amount sufficient to oxidize 80% to 90% of the NO concentration in the flue gas stream to NO₂.

[84] In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 10% to 80% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 20% to 70% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 30% to 60% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 30% to 50% of the NO concentration in the flue gas stream to NO₂. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 40% to 50% of the NO concentration in the flue gas stream to NO₂.

[85] In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is 0.1 wt% H₂O₂ to 30 wt% H₂O₂ based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is 1 wt% H₂O₂ to 30 wt% H₂O₂ based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is 5 wt% H₂O₂ to 30 wt% H₂O₂ based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is 10 wt% H₂O₂ to 30 wt% H₂O₂ based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the flue gas stream is 15 wt% H₂O₂ to 30 wt% H₂O₂ based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H₂O₂ that is introduced into the

flue gas stream is 20 wt% H_2O_2 to 30 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 25 wt% H_2O_2 to 30 wt% H_2O_2 based on a total weight of the flue gas stream.

[86] In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 0.1 wt% H_2O_2 to 25 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 0.1 wt% H_2O_2 to 20 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 0.1 wt% H_2O_2 to 15 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 0.1 wt% H_2O_2 to 10 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 0.1 wt% H_2O_2 to 5 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 0.1 wt% H_2O_2 to 1 wt% H_2O_2 based on a total weight of the flue gas stream.

[87] In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 1 wt% H_2O_2 to 25 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 5 wt% H_2O_2 to 20 wt% H_2O_2 based on a total weight of the flue gas stream. In some embodiments, the sufficient amount of H_2O_2 that is introduced into the flue gas stream is 10 wt% H_2O_2 to 15 wt% H_2O_2 based on a total weight of the flue gas stream.

[88] In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO_2 results in the NO_2 having an upstream concentration in a range from 2% to 99% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the

NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 10 % to 99% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 25% to 99% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 50% to 99% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 75% to 99% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 90% to 99% of a total concentration of the NO_x compounds.

[89] In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 2% to 90% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 2% to 75% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 2% to 50% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 2% to 25% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the

NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 2% to 10% of a total concentration of the NO_x compounds.

[90] In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 10% to 90% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 10% to 75% of a total concentration of the NO_x compounds. In some embodiments, the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration in a range from 25% to 50% of a total concentration of the NO_x compounds.

[91] In some embodiments, the concentration of NO₂ is increased by introducing additional NO₂ into the flue gas stream. In some embodiments, at least some of the additional NO₂ is introduced by oxidizing at least some of the NO in the flue gas stream to NO₂ with the at least one oxidizing agent described herein. In some embodiments, the additional NO₂ is introduced directly into the flue gas stream, e.g., by at least one gas injection system. In some embodiments, additional NO₂ may be introduced by a combination of direct introduction and oxidization. In some embodiments, introducing additional NO₂ comprises removing at least some of the NO in the flue gas stream from the flue gas stream, oxidizing the NO to NO₂, and reintroducing at least some of the resulting NO₂ into the flue gas stream. In some embodiments, the resulting NO₂ may be reintroduced into the flue gas stream as a gas mixture comprising NO and NO₂.

[92] In some embodiments, the increasing of the NO_x removal efficiency of the at least one filter medium further comprises adding ammonia (NH₃). In some embodiments, cleaning a flue gas stream (as described herein, *infra*) comprises adding NH₃. In some embodiments, a combination

of cleaning the flue gas stream and regenerating the at least one filter medium comprises adding NH_3 .

[93] In some embodiments, NH_3 is added in a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream. In some embodiments, NH_3 is added in a concentration ranging from 0.001% to 0.5% of the concentration of the flue gas stream. In some embodiments, NH_3 is added in a concentration ranging from 0.01% to 0.5% of the concentration of the flue gas stream. In some embodiments, NH_3 is added in a concentration ranging from 0.1% to 0.5% of the concentration of the flue gas stream.

[94] In some embodiments, NH_3 is added in a concentration ranging from 0.0001% to 0.1% of the concentration of the flue gas stream. In some embodiments, NH_3 is added in a concentration ranging from 0.0001% to 0.05% of the concentration of the flue gas stream. In some embodiments, NH_3 is added in a concentration ranging from 0.0001% to 0.005% of the concentration of the flue gas stream.

[95] In some embodiments, NH_3 is added in a concentration ranging from 0.005% to 0.1% of the concentration of the flue gas stream. In some embodiments, NH_3 is added in a concentration ranging from 0.005% to 0.05% of the concentration of the flue gas stream.

[96] In some embodiments, the NO_x removal efficiency of the at least one filter medium is at least 0.5% higher after the increasing step than during the providing step. In some embodiments, the NO_x removal efficiency of the at least one filter medium is at least 1 % higher after the increasing step than during the providing step. In some embodiments, the NO_x removal efficiency of the at least one filter medium is at least 5 % higher after the increasing step than during the providing step. In some embodiments, the NO_x removal efficiency of the at least one filter medium is at least 10 % higher after the increasing step than during the providing step. In some

embodiments, the NO_x removal efficiency of the at least one filter medium is at least 25 % higher after the increasing step than during the providing step. In some embodiments, the NO_x removal efficiency of the at least one filter medium is at least 50 % higher after the increasing step than during the providing step. In some embodiments, the NO_x removal efficiency of the at least one filter medium is at least 75 % higher after the increasing step than during the providing step. In some embodiments, the NO_x removal efficiency of the at least one filter medium is at least 100 % higher after the increasing step than during the providing step.

[97] In some embodiments, the increasing of the NO_x removal efficiency comprises removing at least some of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium. In some embodiments, removing at least some of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium may regenerate the at least one filter medium, as described herein.

[98] In some embodiments, the increasing of the NO_x removal efficiency comprises removing at least 10% of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium. In some embodiments, the increasing of the NO_x removal efficiency comprises removing at least 25% of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium. In some embodiments, the increasing of the NO_x removal efficiency comprises removing at least 50% of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium. In some embodiments, the increasing of the NO_x removal efficiency comprises removing at least 75% of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium. In some embodiments, the increasing of the NO_x removal efficiency comprises removing at least 95% of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium. In some embodiments, the

increasing of the NO_x removal efficiency comprises removing all of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium.

[99] In some embodiments, after the step of increasing the NO_x removal efficiency, 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. In some embodiments after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 90% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 50% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 20% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 10% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 5% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.01% to 1% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one

filter medium in a concentration ranging from 0.01% to 0.1% by mass of the at least one filter medium.

[100] In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.1% to 98% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 1% to 98% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 5% to 98% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 10% to 98% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 20% to 98% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 50% to 98% by mass of the at least one filter medium. In some embodiments after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 90% to 98% by mass of the at least one filter medium.

[101] In some embodiments, after the increasing step, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 0.1% to 90% by mass of

the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 1% to 50% by mass of the at least one filter medium. In some embodiments, after the step of increasing the NO_x removal efficiency, ABS deposits are disposed on the catalyst material of the at least one filter medium in a concentration ranging from 5% to 20% by mass of the at least one filter medium.

[102] Some embodiments of the present disclosure relate to a method of cleaning a flue gas stream. As used herein, “cleaning a flue gas stream” means that after “cleaning a flue gas stream” at least one component (such as, but not limited to, NO, NO₂, or a combination thereof) of the flue gas stream is present at a lower concentration as compared to a concentration of the at least one component prior to “cleaning the flue gas stream.” As described herein, “cleaning a flue gas stream” is not necessarily mutually exclusive with “regenerating at least one filter medium” because, in some embodiments, at least one filter medium, prior to regeneration, may still “clean a flue gas stream,” at a lower efficiency as compared to the “at least one filter medium,” after regeneration.

[103] In some embodiments, at least one filter medium may be regenerated during the cleaning of the flue gas stream. In some embodiments, at least one filter medium may be regenerated before the cleaning of the flue gas stream. In some embodiments, at least one filter medium may be regenerated after the cleaning of the flue gas stream. In some embodiments, a method may comprise switching between configurations of “cleaning a flue gas stream” and “regenerating at least one filter medium.” In some embodiments, at least one step, component, or combination thereof from a method of “cleaning a flue gas stream” may be used in a method of “regenerating at least one filter medium” or vice versa.

[104] In some embodiments, the method of cleaning the flue gas stream may comprise flowing a flue gas stream through a filter medium as described herein, (i.e., transverse to a cross-section of a filter medium, such that the flue gas stream passes through the cross section of the at least one filter medium).

[105] In some embodiments of the method of cleaning the flue gas stream, the flue gas stream may comprise NO_x compounds. In some embodiments, the NO_x compounds may comprise Nitric Oxide (NO), and Nitrogen Dioxide (NO₂). In some embodiments, the flue gas stream may further comprise Sulfur Dioxide (SO₂) and Ammonia (NH₃).

[106] In some embodiments, the SO₂, NH₃, and NO_x compounds are present in an amount of at least 1 mg/m³ based on a total volume of the flue gas stream. In some embodiments, the SO₂, NH₃, and NO_x compounds are present in an amount of at least 2 mg/m³ based on a total volume of the flue gas stream. In some embodiments, the SO₂, NH₃, and NO_x compounds are present in an amount of at least 5 mg/m³ based on a total volume of the flue gas stream. In some embodiments, the SO₂, NH₃, and NO_x compounds are present in an amount of at least 10 mg/m³ based on a total volume of the flue gas stream. In some embodiments, the SO₂, NH₃, and NO_x compounds are present in an amount of at least 25 mg/m³ based on a total volume of the flue gas stream. In some embodiments, the SO₂, NH₃, and NO_x compounds are present in an amount of at least 50 mg/m³ based on a total volume of the flue gas stream. In some embodiments, the SO₂, NH₃, and NO_x compounds are present in an amount of at least 100 mg/m³ based on a total volume of the flue gas stream.

[107] In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining a constant NO_x removal efficiency of the at least one filter medium. As used

herein “a constant NO_x removal efficiency” means that a NO_x removal efficiency of the at least one filter medium does not vary by more than a predetermined amount.

[108] In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining NO_x removal efficiency of the at least one filter medium that does not vary by more than $\pm 0.1\%$. In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining NO_x removal efficiency of the at least one filter medium that does not vary by more than $\pm 0.5\%$. In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining NO_x removal efficiency of the at least one filter medium that does not vary by more than $\pm 1\%$. In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining NO_x removal efficiency of the at least one filter medium that does not vary by more than $\pm 2\%$. In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining NO_x removal efficiency of the at least one filter medium that does not vary by more than $\pm 3\%$. In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining NO_x removal efficiency of the at least one filter medium that does not vary by more than $\pm 4\%$. In some embodiments of the method of cleaning the flue gas stream, the method may include maintaining NO_x removal efficiency of the at least one filter medium that does not vary by more than $\pm 5\%$.

[109] In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 5% to 99% of a total concentration of the NO_x compounds. In some embodiments,

maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 10% to 99% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 25% to 99% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 50% to 99% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 75% to 99% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 95% to 99% of a total concentration of the NO_x compounds.

[110] In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 95% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 75% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range

from 2% to 50% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 25% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 10% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 5% of a total concentration of the NO_x compounds.

[111] In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 5% to 95% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium in a range from 10% to 75% of a total concentration of the NO_x compounds. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium comprises providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 25% to 50% of a total concentration of the NO_x compounds.

[112] In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium may include controlling an NO₂ 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 embodiments, maintaining a constant NO_x removal efficiency of the at least one

filter medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.001% to 0.5% of the concentration of the flue gas stream. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.01% to 0.5% of the concentration of the flue gas stream. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.1% to 0.5% of the concentration of the flue gas stream.

[113] In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.0001% to 0.1% of the concentration of the flue gas stream. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.0001% to 0.01% of the concentration of the flue gas stream. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.0001% to 0.001% of the concentration of the flue gas stream.

[114] In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.001% to 0.1% of the concentration of the flue gas stream. In some embodiments, maintaining a constant NO_x removal efficiency of the at least one filter

medium may include controlling an NO₂ concentration, measured from the downstream side of the filter medium, to a range of from 0.01% to 0.1% of the concentration of the flue gas stream.

[115] In some embodiments NO_x efficiency is maintained in an amount of at least 70% of an initial NO_x efficiency. In some embodiments NO_x efficiency is maintained in an amount of at least 75% of an initial NO_x efficiency. In some embodiments NO_x efficiency is maintained in an amount of at least 80% of an initial NO_x efficiency. In some embodiments NO_x efficiency is maintained in an amount of at least 85% of an initial NO_x efficiency. In some embodiments NO_x efficiency is maintained in an amount of at least 90% of an initial NO_x efficiency. In some embodiments NO_x efficiency is maintained in an amount of at least 95% of an initial NO_x efficiency. In some embodiments NO_x efficiency is maintained in an amount of at least 99% of an initial NO_x efficiency.

[116] In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 70% to 99% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 75% to 99% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 80% to 99% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 85% to 99% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 90% to 99% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 95% to 99% of the initial NO_x efficiency.

[117] In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 70% to 95% of the initial NO_x efficiency. In some embodiments, the NO_x

removal efficiency of the at least one filter medium is maintained in a range of 70% to 90% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 70% to 85% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 70% to 80% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 70% to 75% of the initial NO_x efficiency.

[118] In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 75% to 95% of the initial NO_x efficiency. In some embodiments, the NO_x removal efficiency of the at least one filter medium is maintained in a range of 80% to 90% of the initial NO_x efficiency.

[119] In some embodiments, NO_x efficiency is maintained by increasing NO₂. In some embodiments, NO₂ is increased periodically. In some embodiments, NO₂ is increased continuously. In some embodiments, the periodic addition of NO₂ occurs at constant time intervals. In some embodiments, the periodic addition of NO₂ occurs at variable time intervals. In some embodiments, the periodic addition of NO₂ occurs at random time intervals.

[120] In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 40,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 10 to 40,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 100 to 40,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1,000 to 40,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 5,000 to 40,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 10,000 to 40,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 20,000 to 40,000 hours. In some

embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 30,000 to 40,000 hours.

[121] In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 30,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 20,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 10,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 5,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 1,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 100 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1 to 10 hours.

[122] In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 10 to 30,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 100 to 20,000 hours. In some embodiments, the periodic addition of NO₂ comprises increasing NO₂ every 1,000 to 5,000 hours.

[123] In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 5% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 10% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 20% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 30% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous

addition of the NO₂ comprises providing NO₂ at a flow rate of 40% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 50% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 60% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 70% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 80% to 99% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 95% to 99% of a total flow rate of the upstream NO_x compounds.

[124] In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 95% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 90% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 80% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 70% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 60% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 50% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 40% of a total flow rate of the upstream NO_x compounds.

compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 30% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 20% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 10% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 5% of a total flow rate of the upstream NO_x compounds.

[125] In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 5% to 95% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 10% to 90% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 20% to 80% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 30% to 70% of a total flow rate of the upstream NO_x compounds. In some embodiments, the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 40% to 60% of a total flow rate of the upstream NO_x compounds.

[126] Figures 1A-1D depict embodiments of an exemplary filter medium according to the present disclosure.

[127] Referring to Figure 1A, at least one filter medium 101 may be housed in at least one filter bag 100. A flue gas stream 102 may flow through the at least one filter medium 101 by passing through cross section A. Once the flue gas stream 102 flows through the at least one filter medium

101, the flue gas stream 102 may flow by the at least one filter bag, as indicated by the vertically oriented arrows.

[128] Figure 1B depicts an exemplary filter medium 101 according to some embodiments of the present disclosure. As shown in Figure 1B, a flue gas stream 102, which may comprise NO_x compounds and solid particulates 107, may flow through cross section A from an upstream side 103 of the filter medium 101 to a downstream side 104 of the filter medium. While not shown, the upstream side 103 of the filter medium 101 may, in some embodiments, correspond to an outside of a filter bag, such as filter bag 100. Likewise, downstream side 104 of the filter medium 101 may correspond to an inside of a filter bag, such as filter bag 100. In some embodiments, filter medium 101 may include at least one protective membrane 106 and one or more felt batts 108 on at least one of: the upstream side 103 of the filter medium 101, the downstream side 104 of the filter medium 101, or any combination thereof. In some embodiments, the one or more felt batts 108 may be positioned on a porous catalytic film 105. In some embodiments, the combination of the one or more felt batts 108 and the porous catalytic film 105 may be referred to as a porous catalytic layer (not shown in Figure 1B).

[129] Figure 1C depicts a non-limiting exemplary embodiment of the porous catalytic film 105. As shown, porous catalytic film 105 may include catalyst particles 109 on at least one surface of the porous catalytic film 105. ABS deposits 110 may be disposed on the surface of the catalyst particles 109.

[130] Figure 1D depicts an additional non-limiting exemplary embodiment of a filter medium 101. As shown, filter medium 101 may comprise a porous catalytic layer 111. In some non-limiting embodiments, filter medium 101 may take the form of a filter bag. In some embodiments the porous catalytic layer 111 may be coated with a catalyst material (not shown in Figure 1D) such

as catalyst particles. In some embodiments, the catalyst material may be attached to the porous catalytic layer 111 by one or more adhesives described herein (not shown). In some embodiments, the filter medium 101 may include a porous protective membrane 106.

[131] At least some non-limiting aspects of the present disclosure will now be described with reference to the following numbered embodiments hereinafter designated as [E1, E2, E3, E4...]:

E1. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

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

wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds,

wherein the method regenerates the at least one filter medium.

E2. 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), ammonium sulfate (AS), or any combination thereof;

flowing a flue gas stream through or by the at least one filter medium;

wherein the flue gas stream comprises:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

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

wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds;

wherein the increasing of the NO_x removal efficiency of the at least one filter medium further comprises adding ammonia (NH₃) in a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream;

wherein the method regenerates the at least one filter medium.

E3. The method of any of the preceding embodiments or any combination thereof, wherein the temperature of the flue gas stream ranges from 160 °C to 280 °C during the flowing step.

- E4. The method of any of the preceding embodiments, or any combination thereof, wherein the flue gas stream further comprises at least one of Oxygen (O_2), Water (H_2O), Nitrogen (N_2), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Sulfur Trioxide (SO_3), one or more hydrocarbons, or any combination thereof.
- E5. The method of embodiment 2, wherein the flue gas stream is flowed 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.
- E6. The method of embodiment 2, wherein the flue gas stream is not flowed transverse to a cross-section of the at least one filter medium, such that the flue gas stream does not pass through the cross section of the at least one filter medium.
- E7. The method of embodiment 1, 3-5, or any combination thereof, wherein the flue gas stream is flowed perpendicular to a cross-section of the at least one filter medium.
- E8. The method of embodiment 6, wherein the flue gas stream is flowed parallel to a cross-section of the at least one filter medium.
- E9. The method of embodiments 1, 3-5, 7, or any combination thereof, 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.

E10. The method of any of embodiments 1, 3-5, 7, 9, or any combination thereof, wherein the at least one filter medium comprises a porous protective layer and a porous catalytic layer, wherein the porous catalytic layer comprises the at least one catalyst material.

E11. The method of embodiment 10, wherein the porous protective layer comprises a microporous layer, wherein the microporous layer comprises an expanded polytetrafluoroethylene (ePTFE) membrane.

E12. The method of any of the preceding embodiments wherein the at least one catalyst material is adhered to the filter medium by at least one adhesive.

E13. The method of embodiment 12, wherein the at least one adhesive is chosen from polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), high molecular weight polyethylene (HMWPE), high molecular weight polypropylene (HMWPP), perfluoroalkoxy alkane (PFA), polyvinylidene fluoride (PVDF), vinylidene fluoride (THV), chlorofluoroethylene (CFE), or any combination thereof.

E14. The method of embodiments, 9-10, 12, or any combination thereof, wherein the porous catalytic layer comprises at least one polymeric substrate.

- E15. The method of embodiment 14, wherein the at least one polymeric substrate comprises a least one of: polytetrafluoroethylene, poly(ethylene-co-tetrafluoroethylene), ultra-high molecular weight polyethylene, polyparaxylylene, polylactic acid, polyimide, polyamide, polyaramid, polyphenylene sulfide, fiberglass, or any combination thereof.
- E16. The method of embodiments, 9-10, 12, wherein the porous catalytic layer includes at least one ceramic substrate.
- E17. The method of embodiment 16, wherein the at least one ceramic substrate comprises ceramic fibers, wherein the ceramic fibers comprise, alkali metal silicates, alkaline earth metal silicates, aluminosilicates, or any combination thereof.
- E18. The method of embodiments 9-10 or any combination thereof, wherein the porous catalytic layer is in the form of a layered assembly comprising a porous catalytic film and one or more felt batts, wherein the one or more felt batts are positioned on at least one side of the porous catalytic film.
- E19. The method of embodiment 18, wherein the one or more felt batts comprise at least one of: 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.

- E20. The method of embodiment 18, 19, or any combination thereof, wherein the porous catalytic film comprises an expanded polytetrafluoroethylene (ePTFE) membrane.
- E21. The method of embodiments 10, 18-19, or any combination thereof, wherein the catalyst particles are enmeshed within the porous catalytic layer.
- E22. The method of embodiments 10, 18-20, or any combination thereof, wherein the porous catalytic layer comprises a least one of: polytetrafluoroethylene (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.
- E23. The method of embodiments 1-8, or any combination thereof, wherein the at least one filter medium is in the form of a ceramic candle, wherein the ceramic candle comprises at least one ceramic material.
- E24. The method of embodiment 16, 17, 22, or any combination thereof, wherein the temperature of the flue gas stream ranges from 170 °C to 450 °C during the flowing step.
- E25. The method of embodiment 23, 24, or any combination thereof, wherein the least one ceramic material is chosen from: silica-aluminate, calcium-magnesium-silicate, calcium-silicate fibers, or any combination thereof.

- E26. The method of embodiments 24-25, or any combination thereof, wherein the at least one catalyst is in the form of catalyst particles, wherein the catalyst particles form a coating on the at least one ceramic material.
- E27. The method of any of the preceding embodiments or any combination thereof, 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.
- E28. The method of any of the preceding embodiments or any combination thereof, 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.
- E29. The method of any of the preceding embodiments or any combination thereof, wherein 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 after the increasing step.

- E30. The method of any of the preceding embodiments or any combination thereof, wherein the concentration of NO_2 is increased by introducing at least one oxidizing agent to the flue gas stream.
- E31. The method of embodiment 21, wherein the at least one oxidizing agent is chosen from: hydrogen peroxide (H_2O_2), ozone (O_3), hydroxyl radical, or any combination thereof.
- E32. The method of embodiment 21, wherein the concentration of NO_2 is increased by introducing additional NO_2 into the flue gas stream.
- E33. The method of embodiments 1, 3, 4, 7, 9-32, or any combination thereof further comprising adding NH_3 in a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream.
- E34. The method of any of the preceding embodiments or any combination thereof, wherein the NO_x removal efficiency of the at least one filter medium is at least 0.5% higher after the increasing step than during the providing step.
- E35. The method of embodiment 2, wherein the at least one filter medium is in the form of at least one of: a filter bag, a honeycomb structure, a monolith structure or any combination thereof.

E36. The method of any of the preceding embodiments or any combination thereof, wherein the increasing of the NO_x removal efficiency comprises removing at least some of the ABS deposits, the AS deposits, or any combination thereof, from the at least one filter medium.

E37. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds; and

controlling NO₂ 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

wherein the method cleans the flue gas stream.

E38. The method of embodiment 37, wherein the SO₂, NH₃, and NO_x compounds are present in an amount of at least 1 mg/m³ based on a total volume of the flue gas stream.

E39. 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 by a cross-section of the at least one filter medium, such that the flue gas stream is flowed parallel to a 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds; and

controlling NO₂ 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

wherein the method cleans the flue gas stream.

E40. The method of embodiment 39, wherein the SO₂, NH₃, and NO_x compounds are present in an amount of at least 1 mg/m³ based on a total volume of the flue gas stream.

E41. The method of embodiment 39, wherein the at least one filter medium is in the form of at least one of: a honeycomb structure, a monolith structure or any combination thereof.

E42. A filter medium comprising:

an upstream side;

a downstream side;

at least one catalyst material; and

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

wherein the filter medium is configured to receive a flow of a flue gas stream transverse to a cross-section of the 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 filter medium to the downstream side of the filter medium;

wherein the flue gas stream comprises:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the at least one filter medium is configured to increase an NO_x removal efficiency of the at least one filter medium upon an increase of to a range from 2% to 99% of a total concentration of the upstream NO_x compounds.

E43. The filter medium of embodiment 42, wherein, the at least one filter medium is configured to further increase an NO_x removal efficiency of the at least one filter medium when ammonia (NH₃) is added in a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream.

E44. A filter medium comprising:

an upstream side;

a downstream side; and

at least one catalyst material;

wherein the filter medium is configured to receive a flow of a flue gas stream transverse to a cross-section of the 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 filter medium to the downstream side of the filter medium;

wherein the flue gas stream comprises:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

wherein the at least one filter medium is configured to maintain a constant NO_x removal efficiency of the at least one filter medium when:

an NO₂ concentration, measured from the upstream side of the filter medium, is provided in a range from 2% to 99% of a total concentration of the NO_x compounds; and

an NO₂ concentration, measured from the downstream side of the filter medium, is controlled to a range of from 0.0001% to 0.5% of the total concentration of the flue gas stream.

E45. A filter medium comprising:

an upstream side;

a downstream side; and

at least one catalyst material;

wherein the filter medium is configured to receive a flow of a flue gas stream by a cross-section of the filter medium, such that the flue gas stream is not flowed transverse to a 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

wherein the at least one filter medium is configured to maintain a constant NO_x removal efficiency of the at least one filter medium when:

an NO₂ concentration, measured from the upstream side of the filter medium, is provided in a range from 2% to 99% of a total concentration of the NO_x compounds; and

an NO₂ concentration, measured from the downstream side of the filter medium, is controlled to a range of from 0.0001% to 0.5% of the total concentration of the flue gas stream.

E46. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the system is configured to increase an NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds.

E47. A filter bag housing comprising:

a filter medium,

wherein the 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; and

a filter bag,

wherein the filter medium is disposed within the filter bag;

wherein the filter bag is disposed within the filter bag

housing;

wherein the filter bag housing is configured to receive a flow of a flue gas stream transverse to a cross-section of the 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 filter medium to the downstream side of the filter medium,

wherein the flue gas stream comprises:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the filter bag housing is configured to increase an NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds.

- E48. The method of embodiments 1 to 41 or any combination thereof, wherein NO₂ is added to the flue gas stream periodically, so as to maintain the NO_x removal efficiency in an amount of at least 70% of an initial NO_x efficiency.
- E49. The method of embodiment 48, wherein the periodic addition of NO₂ comprises increasing NO₂ every 1 to 40,000 hours.
- E50. The method of embodiment 48, 49, or any combination thereof, wherein the periodic addition occurs at constant time intervals.
- E51. The method of embodiment 48, 49, or any combination thereof, wherein the periodic addition occurs at variable time intervals.
- E52. The method of embodiment 51, wherein variable time intervals are random time intervals.
- E53. The method of embodiments 1 to 41 or any combination thereof, wherein NO₂ is added to the flue gas stream continuously, so as to maintain the NO_x removal efficiency in an amount of at least 70% of an initial NO_x efficiency.

E54. The method of embodiment 53 wherein the continuous addition of the NO₂ comprises providing NO₂ at a flow rate of 2% to 99% of a total flow rate of the upstream NO_x compounds.

E55. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining an NO_x removal efficiency of the at least one filter medium in an amount of at least 70% of an initial NO_x efficiency by:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds; and

controlling NO₂ 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

wherein the method cleans the flue gas stream.

E56. The method of embodiment 55, wherein the NO_x removal efficiency of the at least one filter medium is maintained in a range of 70% to 99% of the initial NO_x efficiency.

E57. The method of embodiment 55, 60, or any combination thereof, wherein during the maintaining of the NO_x removal efficiency, the NO₂ concentration is increased periodically.

E58. The method of embodiment 57, wherein the periodic increase of NO₂ comprises increasing NO₂ every 1 to 40,000 hours.

E59. The method of embodiment 57, 58, or any combination thereof, wherein the periodic increase occurs at constant time intervals.

E60. The method of embodiment 57, 58, or any combination thereof, wherein the periodic increase occurs at variable time intervals.

- E61. The method of embodiment 60, wherein variable time intervals are random time intervals.
- E62. The method of any of embodiments 55, 60, or any combination thereof, wherein during the providing of the NO₂ concentration, the NO₂ concentration is provided continuously.
- E63. The method of embodiment 62, wherein the continuous providing of the NO₂ comprises providing NO₂ at a flow rate of 2% to 99% of a total flow rate of the upstream NO_x compounds.
- E64. 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:
NO_x compounds comprising:
Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

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

wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

wherein the method regenerates the at least one filter medium.

E65. The method of embodiment 64, wherein a temperature of the flue gas stream ranges from 160 °C to 280 °C during the flowing step.

E66. The method of embodiment 64 or embodiment 65, wherein the flue gas stream further comprises Oxygen (O₂), Water (H₂O), Nitrogen (N₂), Carbon Monoxide (CO), Sulfur Dioxide (SO₂), Sulfur Trioxide (SO₃), one or more hydrocarbons, or any combination thereof.

E67. The method of any of embodiments 64 to 66, 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.

E68. The method of any of embodiments 64 to 67, 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.

E69. The method of embodiment 68, 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.

E70. The method of embodiment 69, 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.

E71. The method of embodiment 69 or embodiment 70, wherein the porous catalytic layer of the at least one filter medium comprises at least one polymeric substrate.

E72. The method of any of embodiments 69 to 71, wherein the porous catalytic layer comprises at least one ceramic substrate.

E73. The method any of embodiments 69 to 72, wherein the porous catalytic layer comprises polytetrafluoroethylene (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.

E74. The method of any of embodiments 69 to 73, wherein the catalyst particles are enmeshed within the porous catalytic layer.

- E75. The method of any of embodiments 69 to 74, 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.
- E76. The method of embodiment 75, wherein the porous catalytic film comprises an expanded polytetrafluoroethylene (ePTFE) membrane.
- E77. The method of embodiment 75 or 76, 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.
- E78. The method of any of embodiments 64 to 77, 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.

- E79. The method of any of embodiments 64 to 75, 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.
- E80. The method of any of embodiments 64 to 79, wherein, after increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x 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.
- E81. The method of any of embodiments 64 to 80, wherein the increasing of the NO_x 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.
- E82. 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:
 - NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

controlling the NO₂ 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;

wherein the method cleans the flue gas stream.

E83. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the system is configured to increase a NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, and wherein the upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds by introducing additional NO₂ into the flue gas stream.

E84. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a NO_x removal efficiency of the at least one filter medium in an amount of at least 70% of an initial NO_x efficiency by:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

controlling NO₂ 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

wherein the method cleans the flue gas stream.

E85. The method of embodiment 84, wherein maintaining the NO_x removal efficiency comprises maintaining the NO_x removal efficiency in a range of 70% to 99% of the initial NO_x efficiency.

E86. The method of embodiment 84 or 85, wherein maintaining of the NO_x removal efficiency comprises increasing NO₂ concentration periodically.

E87. The method of embodiment 86, wherein increasing NO₂ concentration periodically comprises increasing NO₂ every 1 to 40,000 hours.

E88. The method of embodiment 86 or 87, wherein increasing NO₂ concentration periodically comprises increasing NO₂ at constant time intervals.

E89. The method of embodiment 86 or 87, wherein increasing NO₂ concentration periodically comprises increasing NO₂ at variable time intervals.

E90. The method of embodiment 89, wherein the variable time intervals are random time intervals.

E91. The method of embodiment 84, wherein providing the NO₂ concentration comprises providing the NO₂ concentration continuously.

E92. The method of embodiment 91, further comprising providing the NO₂ concentration continuously comprises providing NO₂ at a flow rate of 2% to 99% of a total flow rate of the upstream NO_x compounds.

E93. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

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

wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein increasing the upstream NO₂ concentration to a range from 2% to 99% of a total

concentration of the upstream NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream;
wherein the method regenerates the at least one filter medium.

E94. The method of embodiment 93, wherein a temperature of the flue gas stream ranges from 160 °C to 280 °C during the flowing step.

E95. The method of embodiment 93 or embodiment 94, wherein the flue gas stream further comprises Oxygen (O₂), Water (H₂O), Nitrogen (N₂), Carbon Monoxide (CO), Sulfur Dioxide (SO₂), Sulfur Trioxide (SO₃), one or more hydrocarbons, or any combination thereof.

E96. The method of any of embodiments 93 to 95, 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.

E97. The method of any of embodiments 93 to 96, 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.

E98. The method of embodiment 97, 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.

E99. The method of embodiment 98, 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.

E100. The method of embodiment 98 or embodiment 99, wherein the porous catalytic layer of the at least one filter medium comprises at least one polymeric substrate.

E101. The method of any of embodiments 98 to 100, wherein the porous catalytic layer comprises at least one ceramic substrate.

E102. The method of any of embodiments 98 to 101, 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.

E103. The method of any of embodiments 98 to 102, wherein the catalyst particles are enmeshed within the porous catalytic layer.

E104. The method of any of embodiments 98 to 103, 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.

E105. The method of embodiment 104, wherein the porous catalytic film comprises an expanded polytetrafluoroethylene (ePTFE) membrane.

E106. The method of embodiment 104, 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.

E107. The method of any of embodiments 93 to 106, 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.

E108. The method of any of embodiments 93 to 107, 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.

- E109. The method of any of embodiments 93 to 108, wherein, after increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x 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.
- E110. The method of any of embodiments 93 to 109, wherein the at least one oxidizing agent is chosen from: hydrogen peroxide (H₂O₂), ozone (O₃), hydroxyl radical, or any combination thereof.
- E111. The method of any of embodiments 93 to 110, wherein the increasing of the NO_x 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.
- E112. The method of embodiment 110 or 111, wherein the at least one oxidizing agent is H₂O₂.
- E113. The method of embodiment 112, wherein the H₂O₂ is introduced into the flue gas stream in a sufficient amount so as to oxidize at least some of the NO in the flue gas stream to NO₂, wherein the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having the upstream concentration of 2% to 99% of the total concentration of the upstream NO_x compounds.

- E114. The method of embodiment 113, wherein the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration of 25% to 50% of the total concentration of the upstream NO_x compounds.
- E115. The method of embodiment 113, wherein the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize at least 30% of the NO concentration in the flue gas stream to NO₂.
- E116. The method of embodiment 113, wherein the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 30% to 50% of the NO concentration in the flue gas stream to NO₂.
- E117. The method of embodiment 113, wherein the sufficient amount of H₂O₂ that is introduced into the flue gas stream is 0.1 wt% H₂O₂ to 30 wt% H₂O₂ based on a total weight of the flue gas stream.
- E118. The method of any of embodiments 93 to 117, further comprising adding ammonia (NH₃) to the flue gas stream.
- E119. The method of embodiment 118, wherein the NH₃ is added a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream.
- E120. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream; and

controlling the NO₂ 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;

wherein the method cleans the flue gas stream.

E121. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the system is configured to increase an NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, and wherein the upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds by introducing at least one oxidizing agent into the flue gas stream.

E122. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a NO_x removal efficiency of the at least one filter medium in an amount of at least 70% of an initial NO_x efficiency by:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream; and

controlling NO₂ 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;

wherein the method cleans the flue gas stream.

E123. A filter medium comprising:

an upstream side;

a downstream side;

at least one catalyst material; and

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

wherein the filter medium is configured to receive a flow of a flue gas stream transverse to a cross-section of the 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 filter medium to the downstream side of the filter medium;

wherein the flue gas stream comprises:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the at least one filter medium is configured to increase a NO_x removal efficiency of the at least one filter medium upon an increase of upstream NO₂ to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein the increase of upstream NO₂ to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream.

E124. A filter medium comprising:

an upstream side;

a downstream side;

at least one catalyst material; and

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

wherein the filter medium is configured to receive a flow of a flue gas stream transverse to a cross-section of the 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 filter medium to the downstream side of the filter medium;

wherein the flue gas stream comprises:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the at least one filter medium is configured to increase a NO_x removal efficiency of the at least one filter medium upon an increase of upstream NO₂ to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein the increase of upstream NO₂ to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing additional NO₂ into the flue gas stream.

EXAMPLES

[132] Example 1: In-situ “flow-through” regeneration of filter medium including a catalyst coated composite article by NO and NO₂ gas mixture

[133] An exemplary filter medium including a non-limiting example of a catalyst material in the form of a catalyst coated composite article was prepared on a porous substrate having active catalyst particles adhered to the surface by a polymer adhesive according to United States Patent No. 6,331,351.

[134] In-situ “flow-through” regeneration by NO and NO₂ mixture

[135] The filter medium including the catalyst coated composite sample was returned from the field after exposure to a flue gas stream. The deposition of ammonium bisulfate on the returned sample was confirmed by Fourier-transform infrared spectroscopy (FTIR, Thermal Nicolet iS50). During an in-situ regeneration, a 4.5 inch (~1.77 cm) x 4.5 inch (~1.77 cm) sample filter medium including a catalyst coated composite sample was placed in a reactor. A gas mixture including 310 ppm NO, 330 ppm NO₂, 4% O₂, 8% water moisture and N₂ was set to flow-through the catalyst coated composite sample at 230 °C with a total flowrate of 2 L/min. The gas phase NO and NO₂ concentration were monitored with a MKS MULTI-GASTM 2030D FTIR analyzer (MKS Instruments, Andover, MA). The NO and NO₂ gas mixture was obtained by partially oxidizing NO to NO₂ by O₃ generated from the TG-20 O₃ generator (Ozone solutions, Hull, IA). NO_x

removal efficiency was measured before in-situ regeneration treatment and 2, 4, 6, 8, 10 hours after in-situ regeneration treatment.

[136] NO_x reaction efficiency

[137] The filter medium including the catalyst coated composite article was tested for catalytic NO_x removal efficiency from a simulated flue gas at 230 °C. The simulated flue gas contained 200 ppm NO, 200 ppm NH₃, 5% O₂, and N₂ with a total flowrate of 3.4 L/min. To determine NO_x removal efficiency, the upstream (i.e., the concentration of NO_x entering into the chamber before exposure to the filter medium) and downstream concentration (i.e. the concentration of NO_x exiting the chamber after exposure to the filter medium) of NO were monitored with a MKS MULTI-GAS™ 2030D FTIR analyzer (MKS Instruments, Andover, MA). NO_x removal efficiency was calculated according to the following formula where 'NO' indicates the concentration of NO in the respective stream.

[138] NO_x removal efficiency ("DeNO_x") (%) = (NO in – NO out)/NO in × 100%.

[139] Results are shown in Figure 2. The improved NO_x removal efficiency over time, shown in Figure 2, demonstrates that the filter medium was successfully regenerated.

[140] **Example 2: in-situ "flow-through" regeneration of filter medium including a catalytic composite article by NO and NO₂ gas mixture:**

[141] A filter medium including a catalytic composite article is formed according to International Publication No. WO 2019/099025. The filter medium included a catalytic composite article having a layered assembly that included a polytetrafluoroethylene (PTFE) + catalyst composite membrane having a first, upstream side and a second, downstream side; and one or more felt batts. Each felt batt was formed of fleece formed from PTFE staple fiber. Th filter medium was connected together by a plurality of perforations formed by a needle punching process, by a needling process, or both.

[142] The PTFE + catalyst composite membrane of the filter medium described above were prepared using the general dry blending methodology taught in United States Patent No. 7,791,861. to form composite tapes that were then uniaxially expanded according to the teachings of U.S. Patent No. 3,953,556. The resulting porous fibrillated expanded PTFE (ePTFE) composite membranes included supported catalyst particles durably enmeshed and immobilized with the ePTFE node and fibril matrix.

[143] *In-situ “flow-through” regeneration by NO and NO₂ mixture*

[144] The sample filter medium including the sample catalytic composite article described above was in-situ fouled by 400 ppm NO, 440 ppm NH₃, 3000 ppm SO₂ and 8% water moisture at 230 °C and returned from Innovative combustion Technologies (ICT). During an in-situ regeneration, a particular filter medium including a square catalytic composite sample (4.5 inch x 4.5 inch) returned from ICT was placed in a reactor. A gas mixture including 330 ppm NO, 330 ppm NO₂, 4% O₂, 8% water moisture, and N₂ was set to flow-through the catalytic composite sample at 230 °C with a total flowrate of 2 L/min. The NO and NO₂ gas mixture was obtained by partially oxidizing NO to NO₂ by O₃ generated from the TG-20 O₃ generator (Ozone solutions, Hull, IA). NO_x removal efficiency was measured before in-situ regeneration treatment and 4, 10, 15, 21, 24 hours after in-situ regeneration treatment. The downstream (i.e. the concentration of NO_x exiting the chamber after exposure to the filter medium) gas phase NO and NO₂ concentrations were monitored with a MKS MULTI-GAS™ 2030D FTIR analyzer (MKS Instruments, Andover, MA).

[145] *NO_x reaction efficiency*

[146] The filter medium including the sample catalytic composite article was tested for catalytic NO_x removal efficiency at 230 °C from a simulated flue gas. The simulated flue gas contained 200 ppm NO, 200 ppm NH₃, 5 vol% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4

L/min. In order to determine NO_x removal efficiency, the upstream (i.e., the concentration of NO_x entering into the chamber before exposure to the filter medium) and downstream concentration (i.e. the concentration of NO_x exiting the chamber relative after exposure to the filter medium) of NO were monitored with a MKS MULTI-GASTM 2030D FTIR analyzer (MKS Instruments, Andover, MA). NO_x removal efficiency was calculated according to the following formula where 'NO' indicates the concentration of NO in the respective stream.

[147] $\text{NO}_x \text{ removal efficiency ("DeNO}_x\text{") (\%)} = (\text{NO in} - \text{NO out}) / \text{NO in} \times 100\%$

[148] $\text{Relative DeNO}_x \text{ removal efficiency (\%)} = \text{DeNO}_x \text{ after regeneration} / \text{DeNO}_x \text{ of a fresh control sample.}$

[149] Results are shown in Figures 3 and 4. The improved NO_x removal efficiency over time, shown in Figures 3 and 4, demonstrates that the filter medium was successfully regenerated.

[150] **Example 3: in-situ "flow-through" regeneration of filter medium including a catalytic composite article by NO, NO₂ and NH₃ gas mixture**

[151] A catalytic composite article was used as described in Example 2.

[152] *In-situ flow-through regeneration by NO, NO₂, and NH₃ mixture*

[153] Sample filter medium including the sample catalytic composite article described in Example 2 in-situ fouled by 400 ppm NO, 440 ppm NH₃, 3000 ppm SO₂ and 8% water moisture at 230 °C and returned from Innovative combustion Technologies (ICT). During an in-situ regeneration, a particular filter medium including a square catalytic composite sample (4.5 inch × 4.5 inch) returned from ICT was placed in a reactor. A gas mixture including 330 ppm NO, 330 ppm NO₂, 85 ppm NH₃, 4% O₂, 8% water moisture, and N₂ was set to flow-through the catalytic composite sample at 230 °C with a total flowrate of 2 L/min. The NO + NO₂ gas mixture was obtained by partially oxidizing NO to NO₂ by O₃ generated from the TG-20 O₃ generator (Ozone

solutions, Hull, IA). NO_x removal efficiency was measured before in-situ regeneration treatment and 4, 10, 15, 21 hours after in-situ regeneration treatment. The downstream (i.e. the concentration of NO_x exiting the chamber after exposure to the filter medium) gas phase NO and NO₂ concentrations were monitored with a MKS MULTI-GAS™ 2030D FTIR analyzer (MKS Instruments, Andover, MA).

[154] NO_x reaction efficiency

[155] The filter medium including the sample catalytic composite article was tested for catalytic NO_x removal efficiency at 230 °C from a simulated flue gas as described in Example 2.

[156] NO_x removal efficiency (“DeNO_x”) (%) = (NO in – NO out)/NO in × 100%

[157] Relative DeNO_x removal efficiency (%) = DeNO_x after regeneration/DeNO_x of a fresh control sample.

[158] Results are shown in Figures 5 and 6. The improved NO_x removal efficiency over time, shown in Figures 5 and 6, demonstrates that the filter medium was successfully regenerated.

[159] **Example 4: In-situ “flow-by” regeneration of filter medium including a catalytic composite article by NO, NO₂ and NH₃ gas mixture:**

[160] A catalytic composite article as described in Example 2 was used.

[161] In-situ “flow-by” regeneration by NO, NO₂, and NH₃ mixture

[162] A sample filter medium including the sample catalytic composite article described in Example 2 in-situ fouled by 400 ppm NO, 440 ppm NH₃, 3000 ppm SO₂ and 8% water moisture at 230 °C and returned from Innovative combustion Technologies (ICT). During an in-situ regeneration, a particular filter medium including a square catalytic composite sample (4.5 inch × 4.5 inch) returned from ICT was wrapped around a hollow elliptic cylinder stainless steel mesh

and placed in a reactor. A gas mixture including 330 ppm NO, 330 ppm NO₂, 85 ppm NH₃, 4% O₂, 8% water moisture, and N₂ was set to flow-by the catalytic composite sample at 230 °C with a total flowrate of 2 L/min. The NO + NO₂ gas mixture was obtained by partially oxidizing NO to NO₂ by O₃ generated from the TG-20 O₃ generator (Ozone solutions, Hull, IA). NO_x removal efficiency was measured before in-situ regeneration treatment and 4 hours after in-situ regeneration treatment.

[163] NO_x reaction efficiency

[164] The filter medium including the sample catalytic composite article was tested for catalytic NO_x removal efficiency at 230 °C from a simulated flue gas as described in Example 2.

[165] NO_x removal efficiency (“DeNO_x”) (%) = (NO in – NO out)/NO in × 100%

[166] Relative DeNO_x removal efficiency (%) = DeNO_x after regeneration/DeNO_x of a fresh control sample.

[167] Results are shown in Figure 7. The improved NO_x removal efficiency over time, shown in Figure 7, demonstrates that the filter medium was successfully regenerated.

[168] **Example 5: In-situ “flow-through” regeneration of filter medium including catalytic filter bags by NO, NO₂ and NH₃ gas mixture**

[169] Four catalytic filter bags (65 mm in diameter, 1630 mm in length) were prepared from the catalytic composite articles described in Example 2.

[170] In-situ deposition of ammonium bisulfate

[171] The filter medium including the sample catalytic filter bags were in-situ fouled at Innovative combustion Technologies by 200 ppm NO, 240 ppm NH₃, 3000 ppm SO₂ and 8% water moisture at 230 °C for 4 hours.

[172] In-situ “flow-through” regeneration by NO, NO₂, and NH₃ mixture

[173] During an in-situ regeneration, a particular filter medium including 4 catalytic filter bags in-situ fouled as described above were used. A gas mixture including 30 ppm NO, 30 ppm NO₂, 8 ppm NH₃, 10% O₂, 8% water moisture, and N₂ was set to flow-through the catalytic filter bags at 230 °C with a total flowrate of 25.3 SCFM for 20 hours.

[174] NO_x reaction efficiency

[175] The filter medium including the sample catalytic filter bags were tested for NO_x removal efficiency at Innovative Combustion Technologies from a simulated flue gas at 230 °C. The simulated flue gas contained 200 ppm NO, 190 ppm NH₃, 10% O₂, 8% water moisture, and N₂ with a total flowrate of 25.3 standard cubic feet per minute (SCFM). In order to determine NO_x removal efficiency, the upstream (i.e., the concentration of NO_x entering into the chamber before exposure to the filter medium) and downstream concentration (i.e. the concentration of NO_x exiting the chamber relative after exposure to the filter medium) of NO and NO₂ were monitored with a MKS MULTI-GASTM 2030D FTIR analyzer (MKS Instruments, Andover, MA). NO_x removal efficiency was calculated according to the following formula where ‘NO_x’ indicates the total concentration of NO and NO₂ in the respective stream.

[176] NO_x removal efficiency (“DeNO_x efficiency”) (%) = (NO_x in – NO_x out)/NO_x in × 100%. Results are shown in Figure 8. The improved NO_x removal efficiency over time, shown in Figure 8, demonstrates that the filter medium was successfully regenerated.

[177] **Example 6: Long term NO_x removal reaction with exposure to SO₂**

[178] A catalytic composite article as described in Example 2 was used.

[179] Long term flow-through DeNO_x reaction by NO, NO₂, and NH₃ mixture (with and without excess NO₂ in the downstream side of the filter medium)

[180] The filter medium including the sample catalytic composite article was tested for catalytic NO_x removal efficiency from a simulated flue gas at 230 °C. The simulated flue gas included 13.5 ppm SO₂, 200 ppm NO_x (NO + NO₂), 200 ppm NH₃, 5% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4 L/min. The NO₂ was introduced from a gas cylinder. The inlet NO₂ concentration was controlled to have excess NO₂ (1-8 ppm) and no excess NO₂ in the downstream (i.e. the concentration of NO_x exiting the chamber after exposure to the filter medium). In order to determine NO_x removal efficiency, the upstream (i.e., the concentration of NO_x entering into the chamber before exposure to the filter medium) and downstream concentration of NO and NO₂ were monitored with a MKS MULTI-GAS™ 2030D FTIR analyzer (MKS Instruments, Andover, MA). NO_x removal efficiency was calculated according to the following formula where 'NO_x' indicates the total concentration of NO and NO₂ in the respective stream.

[181] NO_x removal efficiency ("DeNO_x efficiency") (%) = (NO_x in – NO_x out)/NO_x in × 100%.

Results are shown in Figures 9-11.

[182] **Example 7: In-situ "flow-through" regeneration of filter medium including a catalytic composite article by NO, NO₂ and NH₃ gas mixture with exposure to SO₂**

[183] A catalytic composite article was used as described in Example 2.

[184] In-situ flow-through regeneration by NO, NO₂, and NH₃ mixture with exposure to SO₂ (with controlled NO₂ slip in the downstream side of the filter medium)

[185] Sample filter medium including the sample catalytic composite article described in Example 2 was in-situ fouled by 400 ppm NO, 440 ppm NH₃, 3000 ppm SO₂ and 8% water moisture at 230 °C and returned from Innovative combustion Technologies (ICT). During an in-situ regeneration, a particular filter medium including a square catalytic composite sample (4.5 inch × 4.5 inch) returned from ICT was placed in a reactor. Catalytic NO_x removal efficiency

before regeneration (in the period of 0-2 hours), during regeneration (in the period of 3-51 hours) and after regeneration (in the period of 55-60 hours) were shown in Figure 12. Catalytic NO_x removal efficiency before and after regeneration were tested at 230 °C with 200 ppm NO, 200 ppm NH₃, 5% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4 L/min. During the regeneration, the simulated flue gas included 13.5 ppm SO₂, 200 ppm NO_x (NO + NO₂), 200 ppm NH₃, 5% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4 L/min. The inlet NO₂ concentration was controlled to have excess NO₂ (1-5 ppm, Figure 12) slip in the downstream (i.e. the concentration of NO_x exiting the chamber after exposure to the filter medium). The NO₂ was introduced from a gas cylinder.

[186] In order to determine NO_x removal efficiency, the upstream (i.e., the concentration of NO_x entering into the chamber before exposure to the filter medium) and downstream concentration of NO and NO₂ were monitored with a MKS MULTI-GAS™ 2030D FTIR analyzer (MKS Instruments, Andover, MA). NO_x removal efficiency was calculated according to the following formula where 'NO_x' indicates the total concentration of NO and NO₂ in the respective stream.

[187] NO_x removal efficiency ("DeNO_x efficiency") (%) = (NO_x in – NO_x out)/NO_x in × 100%.

Results are shown in Figure 12.

[188] **Example 8: In-situ "flow-through" regeneration of filter medium including a catalytic composite article by NO, NO₂ and NH₃ gas mixture with exposure to SO₂**

[189] A catalytic composite article was used as described in Example 2.

[190] *In-situ flow-through regeneration by NO, NO₂, and NH₃ mixture with exposure to SO₂ (with controlled NO₂ slip in the downstream side of the filter medium)*

[191] Sample filter medium including the sample catalytic composite article described in Example 2 was in-situ fouled by 400 ppm NO, 440 ppm NH₃, 3000 ppm SO₂ and 8% water

moisture at 230 °C and returned from Innovative combustion Technologies (ICT). During an in-situ regeneration, a particular filter medium including a square catalytic composite sample (4.5 inch × 4.5 inch) returned from ICT was placed in a reactor. Before the in-situ regeneration, catalytic NO_x removal efficiency (Figure 13) was tested at 230 °C with 200 ppm NO, 200 ppm NH₃, 5% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4 L/min. After checking the NO_x removal efficiency before regeneration, a 6.2days (148 hours) in-situ flow-through regeneration was conducted. During the regeneration, the simulated flue gas included 13.5 ppm SO₂, 200 ppm NO_x (NO + NO₂), 200 ppm NH₃, 5% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4 L/min. The inlet NO₂ concentration was controlled to have excess NO₂ (1-12 ppm) slip in the downstream (i.e. the concentration of NO_x exiting the chamber after exposure to the filter medium). The NO₂ was introduced from a gas cylinder. Catalytic NO_x removal efficiency during the in-situ regeneration was shown in Figure 13. After the in-situ regeneration, catalytic NO_x removal efficiency was tested at 230 °C with 200 ppm NO, 200 ppm NH₃, 5% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4 L/min, shown in Figure 13.

[192] To determine NO_x removal efficiency, the upstream (i.e., the concentration of NO_x entering into the chamber before exposure to the filter medium) and downstream concentration of NO and NO₂ were monitored with a MKS MULTI-GASTM 2030D FTIR analyzer (MKS Instruments, Andover, MA). NO_x removal efficiency was calculated according to the following formula where 'NO_x' indicates the total concentration of NO and NO₂ in the respective stream.

[193] NO_x removal efficiency ("DeNO_x efficiency") (%) = (NO_x in – NO_x out)/NO_x in × 100%. Results are shown in Figure 13.

[194]

[195] **Example 9: Long term NO_x removal reaction with exposure to SO₂ with periodic in-situ “flow-through” regeneration of filter medium**

[196] A catalytic composite article was used as described in Example 2.

[197] *Periodic in-situ flow-through regeneration by NO, NO₂, and NH₃ mixture with exposure to SO₂ (with controlled NO₂ slip in the downstream side of the filter medium)*

[198] The filter medium including the sample catalytic composite article described in Example 2 was tested for catalytic NO_x removal efficiency from a simulated flue gas at 230 °C for over 400 hours (16.7 days). The simulated flue gas included 13.5 ppm SO₂, 200 ppm NO, 200 ppm NH₃, 5% O₂, 5% water moisture, and N₂ with a total flowrate of 3.4 L/min. The DeNO_x removal efficiency change with time was shown in Figure 10 and used as raw data (Tested DeNO_x in Figure 14) to extrapolate the long term DeNO_x removal efficiency (Simulated DeNO_x in Figure 14) change with operation time. In-situ flow-through regeneration by NO, NO₂, and NH₃ mixture (with controlled NO₂ slip in the downstream side of the filter medium) will be started once the DeNO_x removal efficiency decreased to 72%, or 78% of the initial DeNO_x removal efficiency (initial DeNO_x removal efficiency was 92%, Figure 14). According to Example 8, after 148 hours (6.2 days) in-situ flow-through regeneration by NO, NO₂, and NH₃ mixture (with controlled NO₂ slip in the downstream side of the filter medium), the DeNO_x removal efficiency can be recovered to 83%, or 90% of the initial DeNO_x removal efficiency (Figure 14). After the first regeneration, periodic in-situ flow-through regeneration can be conducted periodically once the DeNO_x removal efficiency decreased to 72% or 78% of the initial DeNO_x removal efficiency. This process is illustrated in Figure 14.

[199] Example 10: Injection of 1 wt% H₂O₂ solution into a simulated flue gas stream comprising SO₂ and NO

[200] A syringe pump was used to inject 6.1 ml of 1 wt% H₂O₂ solution at a speed of 12.0 ml/hour into a simulated flue gas stream having a flow rate of 3.19 L/min. The simulated flue gas stream comprised 35 ppm SO₂ and 200 ppm NO. The concentration of NO and NO₂ before, during and after the H₂O₂ injection was measured at several different temperatures, namely 174 °C, 189 °C, 195 °C, and 204 °C, by a MKS MULTI-GAS™ 2030D FTIR analyzer (MKS Instruments, Andover, MA).

[201] NO to NO₂ conversion efficiency was calculated based on the NO and NO₂ concentration during the H₂O₂ injection, NO to NO₂ conversion efficiency ("NO to NO₂ conversion") (%) = $\text{NO}_2/(\text{NO} + \text{NO}_2) \times 100\%$.

[202] Results are shown in Figures 15 and 16. As shown in Figures 15 and 16, NO_x removal efficiency can be improved by introducing at least one oxidizing agent, such as but not limited to H₂O₂, into a flue gas stream.

[203] Example 11: Injection of 0.3 wt% H₂O₂ solution into a simulated flue gas stream comprising SO₂ and NO

[204] A syringe pump was used to inject 6.1 ml of 0.3 wt% H₂O₂ solution at a speed of 12.0 ml/hour into a simulated flue gas stream. The simulated flue gas stream had a flow rate of 3.19 L/min and comprised 35 ppm SO₂ and 200 ppm NO. The concentration of NO and NO₂ before, during and after the H₂O₂ injection was measured at two different temperatures, namely 152 °C and 190 °C, by a MKS MULTI-GAS™ 2030D FTIR analyzer (MKS Instruments, Andover, MA).

[205] NO to NO₂ conversion efficiency was calculated based on the NO and NO₂ concentration during the H₂O₂ injection, NO to NO₂ conversion efficiency (“NO to NO₂ conversion”) (%) = $\text{NO}_2/(\text{NO} + \text{NO}_2) \times 100\%$.

[206] Results are shown in Figure 17. As shown in Figure 17, NO_x removal efficiency can be improved by introducing at least one oxidizing agent, such as but not limited to H₂O₂, into a flue gas stream.

[207] Variations, modifications and alterations to embodiments of the present disclosure described above will make themselves apparent to those skilled in the art. All such variations, modifications, alterations and the like are intended to fall within the spirit and scope of the present disclosure, limited solely by the appended claims.

[208] While several embodiments of the present disclosure have been described, it is understood that these embodiments are illustrative only, and not restrictive, and that many modifications may become apparent to those of ordinary skill in the art. For example, all dimensions discussed herein are provided as examples only, and are intended to be illustrative and not restrictive.

[209] Any feature or element that is positively identified in this description may also be specifically excluded as a feature or element of an embodiment of the present as defined in the claims.

[210] The disclosure described herein may be practiced in the absence of any element or elements, limitation or limitations, which is not specifically disclosed herein. Thus, for example, in each instance herein, any of the terms “comprising,” “consisting essentially of” and “consisting of” may be replaced with either of the other two terms. The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention in

the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within.

CLAIMS

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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

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

wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

wherein the method regenerates the at least one filter medium.

2. The method of claim 1, wherein a temperature of the flue gas stream ranges from 160 °C to 280 °C during the flowing step.
3. The method of claim 1 or claim 2, wherein the flue gas stream further comprises Oxygen (O₂), Water (H₂O), Nitrogen (N₂), Carbon Monoxide (CO), Sulfur Dioxide (SO₂), Sulfur Trioxide (SO₃), one or more hydrocarbons, or any combination thereof.
4. The method of any of claims 1 to 3, 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.
5. The method of any of claims 1 to 4, 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.
6. The method of any of claims 1 to 5, 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.
8. The method of claim 6 or claim 7, wherein the porous catalytic layer of the at least one filter medium comprises at least one polymeric substrate.
9. The method of any of claims 6 to 8, wherein the porous catalytic layer comprises at least one ceramic substrate.
10. The method any of claims 6 to 9, 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.
11. The method of any of claims 6 to 10, wherein the catalyst particles are enmeshed within the porous catalytic layer.
12. The method of any of claims 6 to 11, 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.

13. The method of claim 12, wherein the porous catalytic film comprises an expanded polytetrafluoroethylene (ePTFE) membrane.
14. The method of claim 12 or 13, 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.
15. The method of any of claims 1 to 14, 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.
16. The method of any of claims 1 to 15, 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.

17. The method of any of claims 1 to 16, wherein, after increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x 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.
18. The method of any of claims 1 to 17, wherein the increasing of the NO_x 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.
19. 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:
 - NO_x compounds comprising:
 - Nitric Oxide (NO), and
 - Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

controlling the NO₂ 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;

wherein the method cleans the flue gas stream.

20. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the system is configured to increase an NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, and wherein the upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds by introducing additional NO₂ into the flue gas stream.

21. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining an NO_x removal efficiency of the at least one filter medium in an amount of at least 70% of an initial NO_x efficiency by:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing additional NO₂ into the flue gas stream; and

controlling NO₂ 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

wherein the method cleans the flue gas stream.

22. The method of claim 21, wherein maintaining the NO_x removal efficiency comprises maintaining the NO_x removal efficiency in a range of 70% to 99% of the initial NO_x efficiency.
23. The method of claim 21 or 22, wherein maintaining of the NO_x removal efficiency comprises increasing NO₂ concentration periodically.
24. The method of claim 23, wherein increasing NO₂ concentration periodically comprises increasing NO₂ every 1 to 40,000 hours.
25. The method of claim 23 or 24, wherein increasing NO₂ concentration periodically comprises increasing NO₂ at constant time intervals.
26. The method of claim 23 or 24, wherein increasing NO₂ concentration periodically comprises increasing NO₂ at variable time intervals.
27. The method of claim 26, wherein the variable time intervals are random time intervals.

28. The method of claim 21, wherein providing the NO₂ concentration comprises providing the NO₂ concentration continuously.
29. The method of claim 28, further comprising providing the NO₂ concentration continuously comprises providing NO₂ at a flow rate of 2% to 99% of a total flow rate of the upstream NO_x compounds.
30. 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:
 - NO_x compounds comprising:
 - Nitric Oxide (NO), and
 - Nitrogen Dioxide (NO₂); and
 - increasing NO_x removal efficiency of the at least one filter medium;
 - wherein the increasing of the NO_x removal efficiency of the at least one filter medium comprises increasing an upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, wherein increasing the upstream NO₂ concentration to a range from 2% to 99% of a total

concentration of the upstream NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream;
wherein the method regenerates the at least one filter medium.

31. The method of claim 30, wherein a temperature of the flue gas stream ranges from 160 °C to 280 °C during the flowing step.

32. The method of claim 30 or claim 31, wherein the flue gas stream further comprises Oxygen (O₂), Water (H₂O), Nitrogen (N₂), Carbon Monoxide (CO), Sulfur Dioxide (SO₂), Sulfur Trioxide (SO₃), one or more hydrocarbons, or any combination thereof.

33. The method of any of claims 30 to 32, 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.

34. The method of any of claims 30 to 33, 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.

35. The method of claim 34, 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.

36. The method of claim 35, 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.
37. The method of claim 35 or claim 36, wherein the porous catalytic layer of the at least one filter medium comprises at least one polymeric substrate.
38. The method of any of claims 35 to 37, wherein the porous catalytic layer comprises at least one ceramic substrate.
39. The method of any of claims 35 to 37, wherein the porous catalytic layer comprises polytetrafluoroethylene (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.
40. The method of any of claims 35 to 39, wherein the catalyst particles are enmeshed within the porous catalytic layer.

41. The method of any of claims 35 to 40, 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.
42. The method of claim 41, wherein the porous catalytic film comprises an expanded polytetrafluoroethylene (ePTFE) membrane.
43. The method of claim 41, 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.
44. The method of any of claims 30 to 43, 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.

45. The method of any of claims 30 to 44, 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.
46. The method of any of claims 30 to 45, wherein, after increasing the upstream NO₂ concentration to a range from 2% to 99% of a total concentration of the upstream NO_x 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.
47. The method of any of claims 30 to 46, wherein the at least one oxidizing agent is chosen from: hydrogen peroxide (H₂O₂), ozone (O₃), hydroxyl radical, or any combination thereof.
48. The method of any of claims 30 to 47, wherein the increasing of the NO_x 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.
49. The method of claim 47 or 48, wherein the at least one oxidizing agent is H₂O₂.
50. The method of claim 49, wherein the H₂O₂ is introduced into the flue gas stream in a sufficient amount so as to oxidize at least some of the NO in the flue gas stream to NO₂, wherein the oxidation of at least some of the NO in the flue gas stream to NO₂ results in

the NO₂ having the upstream concentration of 2% to 99% of the total concentration of the upstream NO_x compounds.

51. The method of claim 50, wherein the oxidation of at least some of the NO in the flue gas stream to NO₂ results in the NO₂ having an upstream concentration of 25% to 50% of the total concentration of the upstream NO_x compounds.
52. The method of claim 50, wherein the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize at least 30% of the NO concentration in the flue gas stream to NO₂.
53. The method of claim 50, wherein the sufficient amount of H₂O₂ that is introduced into the flue gas stream is an amount sufficient to oxidize 30% to 50% of the NO concentration in the flue gas stream to NO₂.
54. The method of claim 50, wherein the sufficient amount of H₂O₂ that is introduced into the flue gas stream is 0.1 wt% H₂O₂ to 30 wt% H₂O₂ based on a total weight of the flue gas stream.
55. The method of any of claims 30 to 54, further comprising adding ammonia (NH₃) to the flue gas stream.
56. The method of claim 55, wherein the NH₃ is added a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream.

57. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a constant NO_x removal efficiency of the at least one filter medium;

wherein the maintaining a constant NO_x removal efficiency of the at least one filter medium comprises:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of

a total concentration of the NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream; and

controlling the NO₂ 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;

wherein the method cleans the flue gas stream.

58. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the system is configured to increase an NO_x removal efficiency of the at least one filter medium when an upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds, and wherein the upstream NO₂ concentration is increased to a range from 2% to 99% of a total concentration of the upstream NO_x compounds by introducing at least one oxidizing agent into the flue gas stream.

59. 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:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂);

Sulfur Dioxide (SO₂); and

Ammonia (NH₃);

maintaining a NO_x removal efficiency of the at least one filter medium in an amount of at least 70% of an initial NO_x efficiency by:

providing an NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds, wherein providing the NO₂ concentration, measured from the upstream side of the filter medium, in a range from 2% to 99% of a total concentration of the NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream; and

controlling NO₂ 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;

wherein the method cleans the flue gas stream.

60. A filter medium comprising:

an upstream side;

a downstream side;

at least one catalyst material; and

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

wherein the filter medium is configured to receive a flow of a flue gas stream transverse to a cross-section of the 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 filter medium to the downstream side of the filter medium;

wherein the flue gas stream comprises:

NO_x compounds comprising:

Nitric Oxide (NO), and

Nitrogen Dioxide (NO₂); and

wherein the at least one filter medium is configured to increase a NO_x removal efficiency of the at least one filter medium upon an increase of upstream NO₂ to a range from 2% to 99% of a total concentration of the upstream NO_x compounds.

61. The filter medium of claim 60, wherein the increase of upstream NO₂ to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing at least one oxidizing agent into the flue gas stream.

62. The filter medium of claim 60 or 61, wherein the increase of upstream NO₂ to a range from 2% to 99% of a total concentration of the upstream NO_x compounds comprises introducing additional NO₂ into the flue gas stream.