# METHODS FOR REGENERATING A FILTER MEDIUM AND CLEANING FLUE GAS

## FIELD

**[1]** The present disclosure generally relates to one or more of 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 $SO_2$ and 45 tons of Hg each year.

## SUMMARY

**[3]** 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.

**[4]** ~~Some embodiments of t~~The present disclosure relate to a method of regenerating at least one filter medium, the 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 ($NO_2$); wherein the flue gas stream is at a first temperature during the flowing step; 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: adding ammonia ($NH_3$) in a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream; and increasing the temperature of the flue gas stream from the first temperature to a second temperature that exceeds the first temperature.

**[4a]** In one aspect, there is provided a method comprising: providing at least one filter medium; wherein the at least one filter medium comprises: at least one catalyst material; and ammonium bisulfate (ABS), 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 ($NO_2$); wherein the flue gas stream is at a first temperature during the flowing step; 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: adding ammonia ($NH_3$) in a concentration ranging from 0.0001% to 0.5% of the concentration of the flue gas stream; and increasing the temperature of the flue gas stream from the first temperature to a second temperature that exceeds the first temperature; wherein the method regenerates the at least one filter medium.

**[5]** ~~Some embodiments of t~~The present disclosure also relates to a method of cleaning a flue gas stream, the 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 ($NO_2$); Sulfur Dioxide ($SO_2$); and Ammonia ($NH_3$); wherein the flue gas stream is at a first temperature during the flowing step; and 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 increasing the temperature of the flue gas stream from the first temperature to a second temperature that exceeds the first temperature.

**[5a]** In another aspect, there is provided a method comprising: providing at least one filter medium, wherein the at least one filter medium comprises at least one catalyst material; flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through 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 ($NO_2$); Sulfur Dioxide ($SO_2$); and Ammonia ($NH_3$); wherein the flue gas stream is at a first temperature during the flowing step; and 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 increasing the temperature of the flue gas stream from the first temperature to a second temperature that exceeds the first temperature; wherein the method cleans the flue gas stream.

**[6]** ~~Some embodiments of t~~The present disclosure also relates to a method of cleaning a flue gas stream, the 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 ($NO_2$); Sulfur Dioxide ($SO_2$); and Ammonia ($NH_3$); wherein the flue gas stream is at a first temperature during the flowing step; 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 increasing the temperature of the flue gas stream from the first temperature to a second temperature that exceeds the first temperature.

**[6a]** In another aspect, there is provided a method comprising: providing at least one filter medium, wherein the at least one filter medium comprises at least one catalyst material; flowing a flue gas stream 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 ($NO_2$); Sulfur Dioxide ($SO_2$); and Ammonia ($NH_3$); wherein the flue gas stream is at a first temperature during the flowing step; 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 increasing the temperature of the flue gas stream from the first temperature to a second temperature that exceeds the first temperature; wherein the method cleans the flue gas stream.

**[7]** ~~Some embodiments of t~~The present disclosure also relates to a method of cleaning a flue gas stream, the 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 ($NO_2$); Sulfur Dioxide ($SO_2$); and Ammonia ($NH_3$); wherein the flue gas stream is at a first temperature during the flowing step; 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 increasing the temperature of the flue gas stream from the first temperature to a second temperature that exceeds the first temperature.

**[7a]** In another aspect, there is provided a method comprising: providing at least one filter medium wherein the at least one filter medium comprises at least one catalyst material; flowing a flue gas stream transverse to a cross-section of the at least one filter medium, such that the flue gas stream passes through 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 ($NO_2$); Sulfur Dioxide ($SO_2$); and Ammonia ($NH_3$); wherein the flue gas stream is at a first temperature during the flowing step; 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 increasing the temperature of the flue gas

stream from the first temperature to a second temperature that exceeds the first temperature; wherein the method cleans the flue gas stream.

**[8]** In some ~~embodiments~~examples, the second temperature is at least 10 °C higher than the first temperature.

**[9]** In some examples~~embodiments~~, the second temperature is 10 °C to 100 °C higher than the first temperature.

**[10]** In some examples~~embodiments~~, the first temperature ranges from 180 °C to 230 °C.

**[11]** In some examples~~embodiments~~, the second temperature is at least 240 °C.

**[12]** In some examples~~embodiments~~. the second temperature is at most 280 °C

**[13]** In some examples~~embodiments~~, the second temperature ranges from 240 °C to 280 °C.

**[14]** In some examples~~embodiments~~, the second temperature ranges from 240 °C to 260 °C.

**[15]** In some examples~~embodiments~~, a concentration of $SO_2$ in the flue gas stream does not exceed 1000 ppm during the maintaining step.

**[16]** In some examples~~embodiments~~, a concentration of $SO_2$ in the flue gas stream does not exceed 10 ppm during the maintaining step.

## DRAWINGS

**[17]** 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.

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

**[19]** Figure 2 depicts an exemplary $NO_x$ removal efficiency before ammonium bisulfate deposition, after ammonium bisulfate deposition, and after thermal regeneration of filter medium(s) described herein.

**[20]** Figure 3 depicts a comparative $NO_x$ removal efficiency before ammonium bisulfate deposition, after ammonium bisulfate deposition, and after thermal regeneration of filter medium(s) described herein.

**[21]** Figure 4 depicts a further exemplary $NO_x$ removal efficiency before ammonium bisulfate deposition, after ammonium bisulfate deposition, and after thermal regeneration of filter medium(s) described herein.

**[22]** Figure 5 depicts an exemplary $NO_x$ removal efficiency on a catalytic filter sample after ammonium bisulfate deposition and after thermal regeneration described herein.

## DETAILED DESCRIPTION

**[23]** 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