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(54) **METHOD AND APPARATUS FOR TREATING A COMBUSTION PRODUCT STREAM**

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(57) **ABSTRACT**

An apparatus for treating a combustion product stream includes a burner assembly configured to support one or more flames, the burner assembly having at least a portion configured to be driven to or held at one or more first voltages. A collection surface is held at a voltage different than the one or more first voltages to attract particulates charged by the burner assembly.

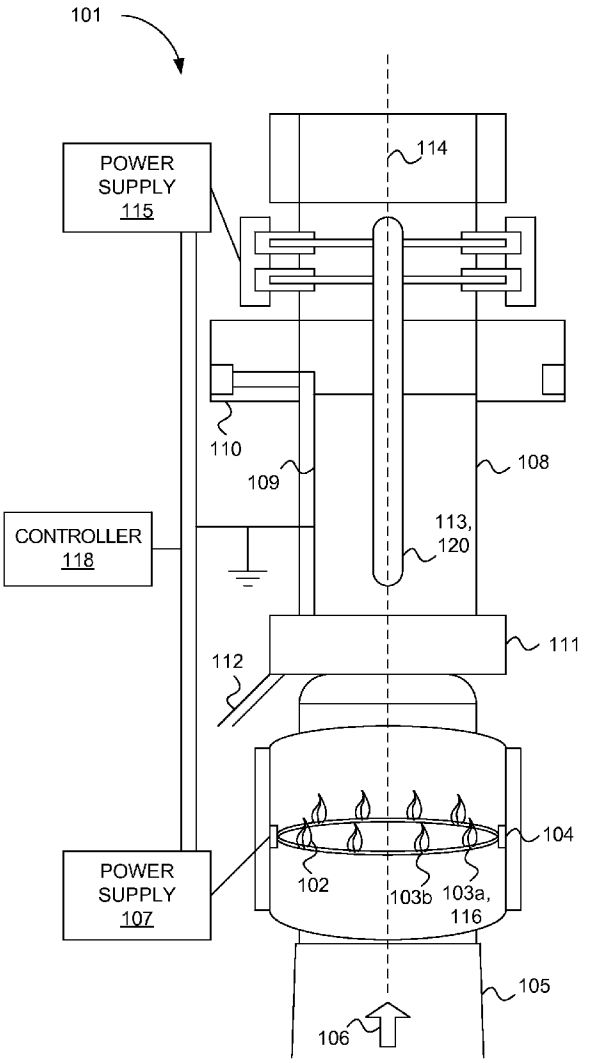


FIG. 1

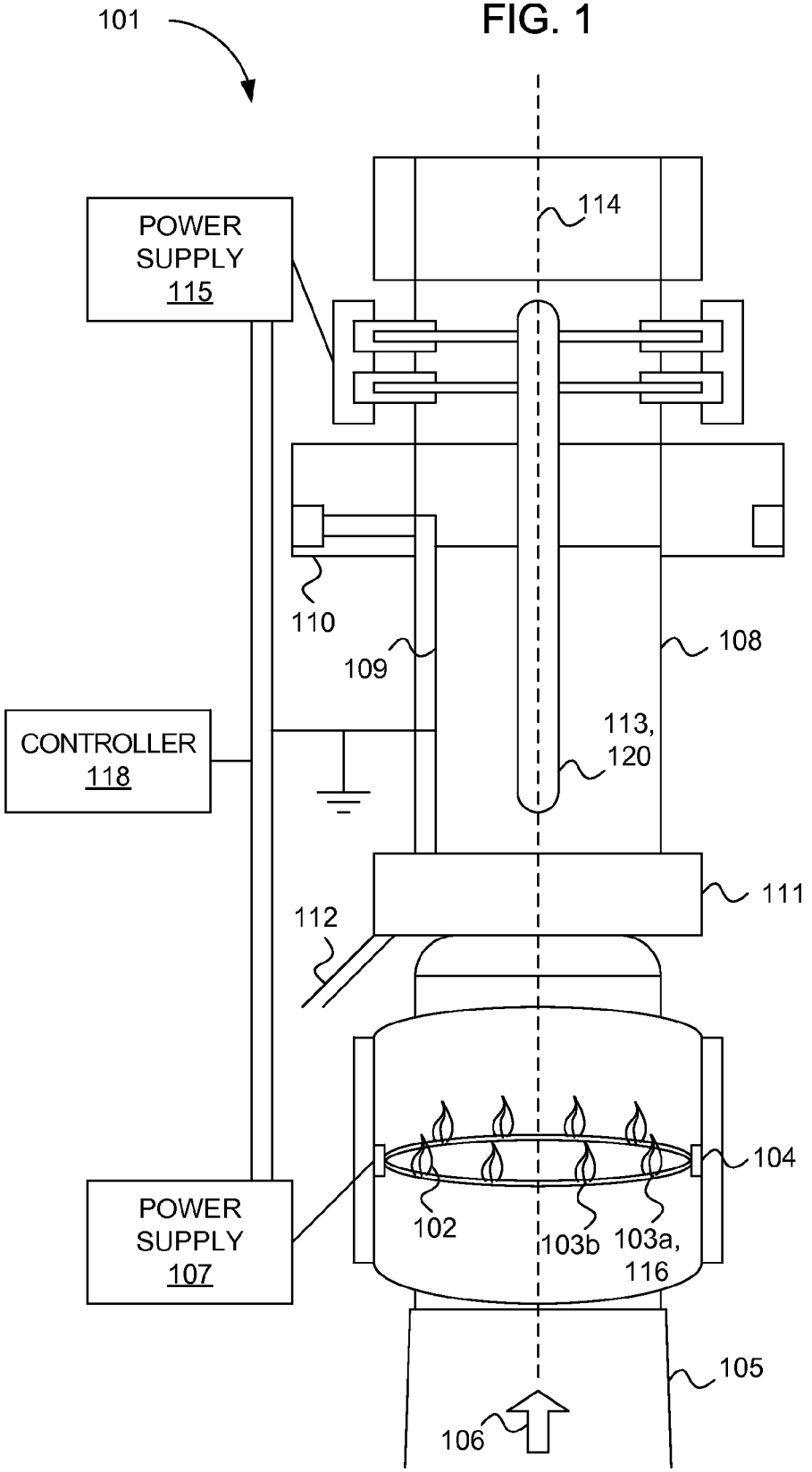

101
POWER SUPPLY 115
114
110
109
108
CONTROLLER 118
113, 120
111
112
104
POWER SUPPLY 107
102
103b
103a, 116
105
106

FIG. 2

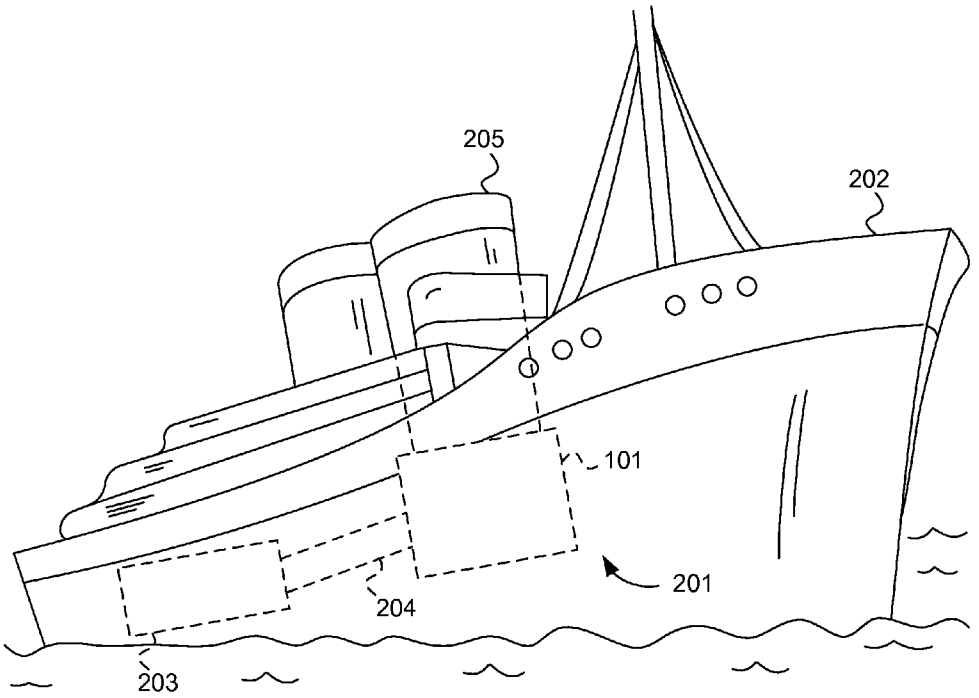
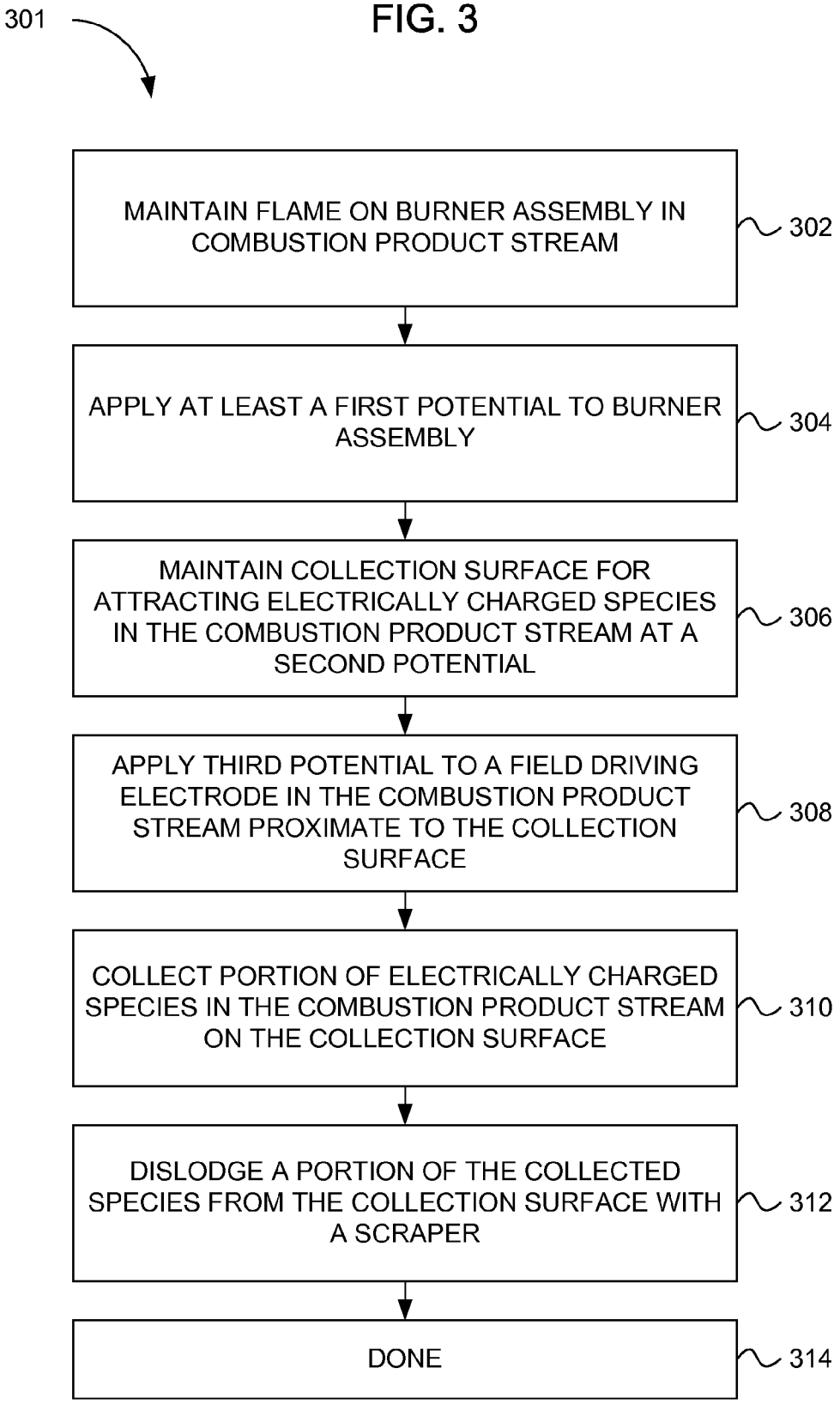


FIG. 3


301
MAINTAIN FLAME ON BURNER ASSEMBLY IN COMBUSTION PRODUCT STREAM
302
APPLY AT LEAST A FIRST POTENTIAL TO BURNER ASSEMBLY
304
MAINTAIN COLLECTION SURFACE FOR ATTRACTING ELECTRICALLY CHARGED SPECIES IN THE COMBUSTION PRODUCT STREAM AT A SECOND POTENTIAL
306
APPLY THIRD POTENTIAL TO A FIELD DRIVING ELECTRODE IN THE COMBUSTION PRODUCT STREAM PROXIMATE TO THE COLLECTION SURFACE
308
COLLECT PORTION OF ELECTRICALLY CHARGED SPECIES IN THE COMBUSTION PRODUCT STREAM ON THE COLLECTION SURFACE
310
DISLODGE A PORTION OF THE COLLECTED SPECIES FROM THE COLLECTION SURFACE WITH A SCRAPER
312
DONE
314

METHOD AND APPARATUS FOR TREATING A COMBUSTION PRODUCT STREAM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority benefit from U.S. Provisional Patent Application No. 61/703,762, entitled "METHOD AND APPARATUS FOR TREATING A COMBUSTION PRODUCT STREAM", filed Sep. 20, 2012; which, to the extent not inconsistent with the disclosure herein, is incorporated by reference.

SUMMARY

[0002] According to an embodiment, an apparatus for treating a combustion product stream includes a burner assembly configured to support one or more flames. The burner assembly includes at least one portion configured to be driven to or held at one or more voltages. A burner support is configured to support the burner assembly in a combustion product stream received from a combustion volume. A collection surface is configured to attract and collect charged species from the combustion product stream.

[0003] According to another embodiment, a system includes a combustion apparatus configured to burn a first fuel and output a combustion product stream and a flue, stack, or pipe configured to convey the combustion product stream from the combustion apparatus. A burner assembly is arranged at a first location in the flue, stack, or pipe, and is configured to burn a second fuel to support one or more flames. An electrode assembly proximate to the burner assembly is configured to be driven to or held at one or more first voltages. A collection surface is arranged at a second location in the flue, stack, or pipe selected to receive the combustion product stream after the combustion product stream flows past the first location. The collection surface is configured to be driven to or held at one or more second voltages or ground different from the first voltage.

[0004] According to another embodiment, a method of treating a combustion product stream includes maintaining a flame at a first location in a substantially non-ionized combustion product stream, the flame producing electrically charged species. At least one first electrical potential is applied proximate to the flame to preferentially attract a portion of the electrically charged species or to output additional electrically charged species having a majority polarity to produce a charge imbalance in the combustion product stream. The electrical charges tend to deposit on and are carried by particulates in the combustion product stream. A collection surface is supported in or adjacent to the combustion product stream at a second location exposed to the charge imbalance. At least one second electrical potential at ground or opposite in polarity to the at least one first electrical potential attracts charged particles from the combustion product stream to the collection surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** is a diagram of an apparatus configured to treat a combustion product stream, according to an embodiment.

[0006] FIG. **2** is a block diagram of a system including an internal or external combustion engine and a combustion product stream treatment apparatus of FIG. **1**, the combustion product stream treatment apparatus being configured to treat a combustion product stream produced by the internal or external combustion engine, according to an embodiment.

[0007] FIG. **3** is a flow chart of a method of treating a combustion product stream, according to an embodiment.

DETAILED DESCRIPTION

[0008] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here.

[0009] FIG. **1** is a diagram of an apparatus **101** configured to treat a combustion product stream, according to an embodiment. The apparatus **101** includes at least one burner assembly **103***a* configured to support a flame **102**. A burner support **104** can support the burner assembly **103***a* in a combustion product stream (having a flow illustrated by the arrow **106**) such as in a flue **105**. The combustion product stream can include combustion reaction gaseous products, intermediates, and particulates such as unburned fuel, hydrocarbons and ash.

[0010] The burner assembly **103***a* includes a first electrode **116** configured to be driven to or held at one or more voltages by a voltage source including a power supply **107**. For example, in an embodiment, the burner assembly **103***a* can be substantially coextensive with the first electrode **116**. The burner assembly **103***a* can include a ring-burner with a plurality of burner nozzles **103***b* operable to respectively support a plurality of flames **102**. Alternatively, other burner designs can be used. The burner nozzle(s) **103***b* is configured to be held at one or more voltages produced by the voltage source including the power supply **107**. The burner assembly **103***a* can support one or more flames **102** that are the product of the combustion of one or more suitable fuels, such as natural gas, propane and/or butane.

[0011] Optionally, the burner assembly **103***a* can be fired by substantially the same fuel that generates the combustion product stream. For example, where the combustion product stream is produced by an internal combustion diesel engine, the flame(s) **102** can be produced by burning diesel fuel; or where the combustion product stream is produced by a heavy fuel boiler or furnace, the flame(s) **102** can be produced by burning heavy pre-heated fuel (e.g. Number 5 fuel oil ("Bunker B") or Number 6 fuel oil ("Bunker C")). The burner assembly **103***a* can be placed at a location in the combustion product stream where the combustion product stream carries a low concentration or substantially no ionized species. For example, charged combustion reaction intermediates can be substantially reacted to form products or byproducts of the combustion reaction. Any residual charged particles or molecules from the originating combustion reaction can be generally neutralized to non-charged forms by the time they reach the burner assembly **103***a*. Flames, including the flame (s) **102**, inherently produce charged or ionized species, generally as reaction intermediates. Applying an electrical potential to the flame(s) **102** causes the flame(s) **102** to carry a voltage or charges having the same polarity as the electrical potential. Accordingly, one function of the flame(s) **102** supported by the burner assembly **103***a* is to introduce charged species into the substantially non-charged combustion prod-

uct stream. In some embodiments, another purpose of the flame(s) **102** is to increase adhesion of particulates to the collection surface **108**.

[0012] According to the laws of conservation of mass and conservation of charge, and absent a structure operable to remove charge and/or mass, the charged species produced by the flame(s) **102** are present in relative quantities or concentrations corresponding to net charge neutrality. That is, for every negative charge produced by the flame(s) **102**, there is a corresponding positive charge. Typically, the positive and negative charges produced by a flame recombine relatively quickly. But, as will be described below, a motive force for attracting pollutants from the combustion product stream relies on the stream carrying a net charge, at least periodically. The first electrode **116** is configured to at least periodically remove a portion of charged species produced by the flame or to supply additional charged species to the flame, such that the net charge is not neutral.

[0013] The first electrode **116** and/or burner assembly **103***a* can be configured to be driven to or held at a voltage using direct-current or using a modulated voltage source with a direct-current offset. For example, the first electrode **116** and/or burner assembly **103***a* can be configured to be driven to or held at a positive voltage so that electrons are at least periodically withdrawn from the one or more flames **102** supported by the burner assembly. This removal of electrons causes a charge imbalance in the flame(s) **102**, and hence in the combustion product stream. For example, the first electrode **116** and/or burner assembly **103***a* can be held at a location in the combustion product stream that is substantially non-ionized, and withdrawing electrons from the combustion product stream can generate ionized species in the combustion product stream that are relatively persistent, due to the lack of counter-ions available for recombination.

[0014] It is believed that applying an electric field to a combustion product stream containing a net charge results in driving charged species so as to have a motion component along field lines. It is also believed that charges introduced to a combustion product stream tend to become affixed to particulates carried by the combustion product stream. Accordingly, the net charge produced by the flame(s) **102** and first electrode **116** tends to affix to particulates. An electric field (a collection field described below) applied to the combustion product stream will drive the charged particulates in one or more directions determined by the electric field and mass flow of the combustion product stream.

[0015] The apparatus **101** includes a collection surface **108** configured to be held at a ground potential or at an electrical potential opposite in polarity from the net charge remaining in the combustion product stream. The collection surface **108** is located downstream within the combustion product stream relative to the burner assembly **103***a* to attract electrically charged species from the combustion product stream. For example, the collection surface **108** can include a cylindrical portion of the flue **105**. Electrically charged species from the combustion product stream are attracted to and collected on the collection surface. Electrically charged species can include electrically charged particulate matter that has received an electric charge from ionized species generated by the flame(s) **102** supported by the burner assembly **103***a* and the first electrode **116**.

[0016] A scraper **109** can be configured to scrape the collection surface **108** to remove particulates collected on the collection surface **108**. For example, where the collection surface **108** is cylindrical, the scraper **109** can be rotated across the collection surface **108** by a scraper assembly **110** to dislodge particulates that have been collected on the collection surface **108**. Particulates that are dislodged from the collection surface **108** can be collected in a particulates receptacle **111**. Particulates collected in the particulates receptacle **111** can be removed via a disposal chute **112**. Optionally, a physical scraper **109** can be replaced by or augmented by one or more other particulate removal apparatus. For example, a sonic or vibratory transducer can shake particles free, a vacuum can suck particles free, or a pressurized gas stream can blow particles off the collection surface **108**.

[0017] The apparatus **101** can include a second electrode **120** and/or field-driving surface **113** configured to be driven to or held at a voltage using direct-current or using a modulated voltage source with a direct-current offset. The second electrode **120** and/or field-driving surface **113** is configured to be driven to or held at a voltage produced by a voltage source including a power supply **115**. The power supplies **107**, **115** can be operatively coupled to controller **118**, which is configured to drive or control the second electrode **120** and/or field-driving surface **113** and the first electrode **116** and/or burner assembly **103***a*.

[0018] Typically, the second electrode **120** and/or field-driving surface **113** can be held or driven to one or more voltages having the same sign as one or more voltages at which the first electrode **116** and/or burner assembly **103***a* is held.

[0019] The second electrode **120** and/or field-driving surface **113** can be arranged in opposition to the collection surface **108**. For example, in an embodiment, the second electrode **120** and/or field-driving surface **113** can comprise a rod supported along an axis **114** and concentrically within the flue **105** the second electrode **120** and/or field-driving surface **113** can be configured to create a radial electric voltage gradient across the combustion product stream between the second electrode **120** and/or field-driving surface **113** and the collection surface **108**. The electric voltage gradient can cause electrically charged particles in the combustion stream to be attracted to the collection surface **108** and can impart a drift velocity in electrically charged particles in the combustion stream.

[0020] For example, if the first electrode and/or burner assembly **103***a* is driven to a modulated voltage with a positive bias; the second electrode **120** and/or field-driving surface **113** is also driven to a positive voltage, either modulated or substantially constant; and the collection surface **108** can be held at ground or driven to a negative voltage, either modulated or substantially constant. In an embodiment, the power supply **107** is configured to output a time-varying first voltage of alternating polarity to the burner assembly **104** and the second electrode **120** and to output a time-varying second voltage of alternating polarity to the collection surface, the time-varying second voltage being substantially opposite in electrical polarity from the time-varying first voltage (i.e., except for times corresponding to voltage inversion and any phase lag between the first and second voltages). Positively charged particles in the combustion product stream are thus repelled by the second electrode **120** and/or field-driving surface **113**, and attracted by the collection surface **108**. This can be used to remove particulates from the combustion product stream.

[0021] The burner support **104** can be configured to support the burner assembly **103***a* in the combustion product stream at

a first location, and the collection surface **108** and field-driving surface **113** can be at a second location selected to cause the combustion product stream to flow past the first location before flowing past the second location. The first and second locations can be selected to provide spatial separation sufficient to allow a charge imbalance within the combustion product stream to associate with particulates within the combustion product stream.

[0022] FIG. **2** is a block diagram of a system **201** including an internal or external combustion engine **203** and a combustion product stream treatment apparatus **101** of FIG. **1**, the combustion product stream treatment apparatus **101** being configured to treat a combustion product stream produced by the internal or external combustion engine **203**, according to an embodiment. The system **201** can comprise an internal combustion engine or a fixed boiler **203** and a pipe **204** configured to convey a combustion product stream to the apparatus **101**. A flue **205** can be operable to convey a combustion product stream from the apparatus **101** to the surrounding environment.

[0023] For example, in an embodiment, a ship **202** can comprise an internal combustion engine or fixed boiler **203** that powers the ship **202** via combustion of a combustion volume of fuel such as diesel, coal or bunker fuel. The internal combustion engine or fixed boiler **203** may generate a combustion product stream, which can include unburned fuel, ash, carbon dioxide (CO_2), oxides of sulfur (SO_X), oxides of nitrogen (NO_X), hydrocarbons, and other species. The combustion product stream can be conveyed via a flue, stack or pipe **204** to the apparatus **101** (FIG. **1**). The apparatus **101** can be configured to remove particulate matter from the combustion gas stream as discussed herein, and pass the remaining combustion gas stream into the environment via a stack, pipe or flue **205**. This is desirable in some embodiments because the combustion product stream discharged into the environment is cleaner and contains less particulate matter and other species than the combustion product stream produced by the internal combustion engine or fixed boiler **203**.

[0024] In embodiments, the apparatus **101** (FIG. **1**) is configured to treat a combustion product stream generated by an internal or external combustion engine **203** powering various vehicles such as boats, ships, trucks, planes, or the like. In other embodiments, the apparatus **101** (FIG. **1**) is configured to treat a combustion product stream generated by internal or external combustion engines **203** associated with a power plant, machinery, a building or other infrastructure, or the like.

[0025] FIG. **3** is a flow chart of a method **301** of treating a combustion product stream according to an embodiment. The method **301** begins with step **302** where a flame on a burner assembly is maintained in a combustion product stream and continues to step **304** where at least a first potential is applied to the burner assembly. Typically, steps **302** and **304** can be performed substantially simultaneously.

[0026] For example, in an embodiment, and referring to FIG. **1**, one or more flames **102** can be maintained on a burner assembly **103***a* in a substantially non-ionized combustion product stream to produce electrically charged species in the combustion product stream. An electric potential is applied to the first electrode **116** and/or burner assembly **103***a*, or otherwise proximate to the one or more flame **102**, which can attract electrically charged species or output electrically charged species (e.g., electrons) from or to the flame(s) **102** responsive to current provided by the potential source. The addition or removal of electrical charges to or from the flame (s) **102** produces a charge imbalance in the flame, which is transferred to particulates in the combustion product stream.

[0027] In an embodiment, charged species can be attracted to particulate matter within the combustion product stream and can attach to particulate matter and create a net charge thereon.

[0028] In one embodiment, a time-varying electric potential can be applied to the burner assembly **103***a* and/or first electrode **116** (e.g., time modulated from positive to negative; modulated from positive to ground; or modulated from negative to ground). In such an embodiment, ionized species can be intermittently withdrawn from the combustion product stream, and a charge imbalance can be produced in the combustion product stream including one or more portions of imbalanced charge. For example, concentric portions of the combustion product stream can have alternating net-positive and net-negative charge, alternating net-positive and neutral charge, or neutral and net-negative charge.

[0029] Returning to FIG. **3**, the method **301** continues to step **306** where a collection surface for attracting electrically charged species is maintained at a second potential. For example, in an embodiment, and referring to FIG. **1**, the collection surface **108** can be held at ground potential and attract positively charged species, which can include particulates that has a net positive charge. As positively charged species travel toward the collection surface **108**, the positively charged species can be attracted to the collection surface **108** and stick or attach thereto. Contact with the collection surface **108** can discharge some or all of the electric charge associated with the charged species.

[0030] Returning again to FIG. **3**, the method continues in optional step **308** wherein a third potential is applied to a field-driving electrode proximate to the collection surface, and in step **310**, a portion of the electrically charged species in the combustion product stream are collected on the collection surface. In step **312**, portions of the collected species are dislodged from the collection surface with a scraper, and the method is done in step **314**.

[0031] For example, in an embodiment, and referring to FIG. **1**, the second electrode **120** and/or field-driving surface **113** can comprise a rod and can be spaced away from the collection surface **108** by at least a portion of the combustion product stream carrying an electric charge imbalance. An electric charge can be applied to the second electrode **120** and/or field-driving surface **113**, which is the same sign as a portion of charged species within combustion product. This can cause the charged species within the combustion product stream to be attracted to (or further attracted to) the collection surface **108**, which can be held at a potential. As discussed above, positively charged species within the combustion product stream can be attracted to the collection surface **108**, and introduction of an electric charge to the second electrode **120** and/or field-driving surface **113** can increase attraction of such charged species to the second electrode **120** and/or field-driving surface **113**.

[0032] As discussed above, particulate matter having a net charge can be attracted to and stick, couple, or adhere to the collection surface **108**, and the charge can be discharged upon contact with the collection surface **108**. In an embodiment, the particulate matter is increased in "stickiness" from heating by the flame(s) **102**. Over time, a layer of particulate matter can accumulate on the collection surface **108**. It can be desirable for such a layer of particulate matter to be removed

from the collection surface **108**. For example, where the collection surface **108** includes a cylindrical surface substantially coincident with a pipe, stack or flue **105** through which a combustion product stream flows, the scraper **109** can be configured to rotate across the collection surface **108** and thereby scrape or dislodge particulate matter that has accumulated on the collection surface **108**.

[0033] In one embodiment, particulates can be removed from the collection surface **108** in other ways, which can include driving a shaker, applying compressed gas, or applying a vacuum to the collection surface **108**.

[0034] In one embodiment, any of the first electrode **116** and/or burner assembly **103***a*, collection surface **108** or second electrode **120** and/or field-driving surface **113** can be configured to be driven to or held at positive, negative, or ground electrical potential. Additionally, a time varying or substantially constant voltage can be applied to any of the burner assembly **103***a*, collection surface **108** or field-driving surface **113** in an embodiment. The first electrode **116** and/or burner assembly **103***a* can be configured to be driven to or held at a voltage using direct-current or using a modulated voltage source with a direct-current offset. The second electrode **120** and/or field-driving surface **113** can be configured to be driven to or held at a voltage using direct-current or using a modulated voltage source with a direct-current offset.

[0035] In one embodiment a reaction that produces charged moieties can not comprise a combustion reaction. For example, in an embodiment, the burner assembly **103***a* can be substituted with a corona wire or other non-combustion source of charged species.

[0036] In one embodiment, the combustion product stream can comprise a liquid stream or comprise liquid (e.g., an aerosol).

[0037] While various aspects and embodiments have been disclosed herein, other aspects and embodiments are contemplated. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

1. An apparatus for treating a combustion product stream, comprising:

a burner assembly configured to support one or more flames, the burner assembly having at least a portion configured to be driven to or held at one or more first voltages;

a burner support configured to support the burner assembly in a combustion product stream received from a combustion volume at a first location;

a power supply operatively coupled to the portion of the burner assembly operable to be driven to or held at one or more first voltages, the power supply being configured to output the first voltage to the burner assembly; and

at least one collection surface in contact with the combustion product stream at a second location selected to cause the combustion product stream to flow past the first location before flowing past the second location, the collection surface being configured to be held at or driven to at least one second voltage or ground different than the at least one first voltage.

2. The apparatus of claim **1**, wherein the burner assembly includes a burner electrode configured to be driven to or held at the one or more first voltages.

3. The apparatus of claim **1**, wherein the burner assembly includes a burner nozzle; and

wherein the portion of the burner assembly configured to be driven to or held at the one or more first voltages includes the burner nozzle.

4. The apparatus of claim **1**, wherein the burner support is configured to hold the burner assembly within a flue configured to receive the combustion product stream from the combustion volume.

5. The apparatus of claim **1**, wherein the burner support is configured to hold the burner assembly at a location in the combustion product stream where the combustion product stream is substantially non-ionized.

6. The apparatus of claim **5**, wherein the one or more flames supported by the burner assembly are configured to provide ionized species to the combustion product stream; and

wherein the at least a portion of the burner assembly operable to be driven to or held at one or more first voltages is configured to at least intermittently withdraw a portion of the ionized species provided by the one or more flames to produce a charge imbalance in the combustion product stream.

7. The apparatus of claim **1**, wherein the burner assembly includes a ring-burner operable to support a plurality of flames.

8. The apparatus of claim **1**, wherein the power supply is configured to output a time-varying first voltage.

9. The apparatus of claim **1**, wherein the one or more first voltages include a positive voltage configured to withdraw electrons from the one or more flames supported by the burner assembly.

10. The apparatus of claim **1**, wherein the one or more first voltages comprise a substantially constant voltage.

11. The apparatus of claim **1**, wherein the power supply is configured to output a time-varying first voltage to the burner assembly; and

wherein the power supply is configured to output a time-varying second voltage to the collection surface, the time-varying second voltage being opposite in electrical polarity from the time-varying first voltage during a majority of instants having finite duration.

12. The apparatus of claim **11**, wherein the combustion product stream includes particulates.

13. The apparatus of claim **11**, wherein the collection surface is configured to attract electrically charged species from the combustion product stream.

14. The apparatus of claim **11**, further comprising:

a scraper operable to scrape the collection surface to remove collected particulates from the combustion gas stream.

15. The apparatus of claim **11**, further comprising a field-driving surface arranged in opposition to the collection surface and separated from the collection surface by at least a portion of the combustion product stream, the field-driving surface being configured to be driven or held to at least one third voltage selected to create an electrical voltage gradient across the at least a portion of the combustion product stream between the field-driving surface and the collection surface.

16. The apparatus of claim **15**, wherein the at least one third voltage corresponds to the at least one first voltage.

17. The apparatus of claim **15**, wherein the field-driving surface includes a rod supported along an axis of a flue through which the combustion product stream flows;

wherein the collection surface includes a surface located concentric to the field driving surface; and

wherein the electrical voltage gradient is formed radially between the field-driving surface and the collection surface.

18. The apparatus of claim **11**, wherein the one or more first voltages are opposite in polarity to the one or more second voltages.

19. A system comprising:

a combustion apparatus operable to burn a first fuel and output a combustion product stream;

a flue, stack, or pipe configured to convey the combustion product stream from the combustion apparatus;

a burner assembly arranged at a first location in the flue, stack, or pipe, operable to burn a second fuel and support one or more flames;

an electrode assembly proximate the burner assembly, configured to be driven to or held at one or more first voltages; and

a collection surface arranged at a second location in the flue, stack, or pipe selected to receive the combustion product stream after the combustion product stream is conveyed past the first location and configured to be driven or held at one or more second voltages or ground different from the first voltage.

20. The system of claim **19**, wherein the combustion apparatus includes an internal combustion engine.

21. The system of claim **19**, wherein the combustion apparatus includes an external combustion power source.

22. The system of claim **19**, wherein the first fuel includes diesel, coal, or bunker fuel.

23. The system of claim **19**, wherein the second fuel includes natural gas, propane, or butane.

24. The system of claim **19**, wherein the first and second fuels are different fuels.

25. The system of claim **19**, wherein the first and second fuels are substantially the same fuel.

26. The system of claim **19**, wherein the burner assembly and the electrode assembly are substantially coextensive.

27. The system of claim **19**, wherein the combustion product stream includes unburned fuel, ash, or unburned fuel and ash;

wherein the burner assembly is configured to provide ionized species to the combustion product stream;

wherein the electrode assembly is configured to cause a charge imbalance in the ionized species;

wherein the unburned fuel, ash, or unburned fuel and ash receive charge corresponding to the charge imbalance to produce charged unburned fuel, ash, or unburned fuel and ash; and

wherein the collection surface is configured to electrically attract the charged unburned fuel, ash, or unburned fuel and ash out of the combustion product stream.

28. A method of treating a combustion product stream, comprising:

maintaining a flame at a first location in a substantially non-ionized combustion product stream to produce electrically charged species;

applying at least one first electrical potential proximate to the flame to preferentially attract a portion of the electrically charged species and produce a charge imbalance in the combustion product stream;

providing a collection surface in or adjacent to the combustion product stream at a second location exposed to the charge imbalance; and

applying at least one second electrical potential at ground or opposite in polarity to the at least one first electrical potential to attract charged particles from the combustion product stream to the collection surface.

29. The method of claim **28**, further comprising:

providing a field-driving electrode proximate to the second location and spaced away from the collection surface by at least a portion of the combustion product stream carrying the charge imbalance; and

applying at least one third electrical potential to the field-driving electrode to create a voltage difference between the field-driving electrode and the collection surface.

30. The method of claim **29**, wherein at least one first electrical potential and the at least one third electrical potential include electrical potentials at the same polarity.

31. The method of claim **30**, wherein the at least one first electrical potential and the at least one third electrical potential include positive electrical potentials.

32. The method of claim **28**, wherein the combustion product stream includes particulates; and further comprising:

selecting first and second locations having a separation sufficient to allow the charge imbalance to associate with the particulates.

33. The method of claim **28**, further comprising:

providing a burner apparatus to support the flame; and

providing fuel to the burner apparatus to maintain the flame.

34. The method of claim **33**, wherein the fuel is different than a second fuel that produced the combustion product stream.

35. The method of claim **33**, wherein applying at least one first electrical potential proximate to the flame includes applying a voltage to at least a portion of the burner apparatus.

36. The method of claim **28**, wherein applying the at least one first electrical potential includes modulating an electrical potential including one or more positive voltages.

37. The method of claim **28**, wherein the collection surface includes a cylindrical surface substantially coincident with a flue, pipe, or stack through which the combustion product stream flows.

38. The method of claim **28**, further comprising:

at least intermittently removing adhered particulates from the collection surface.

39. The method of claim **38**, wherein at least intermittently removing the adhered particulates from the collection surface includes one or more of driving a scraper, driving a shaker, applying compressed gas, or applying a vacuum to the collection surface.

40. The method of claim **28**, wherein applying the at least one second potential or ground to the collection surface substantially removes particulates from the combustion product stream.

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