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(54) **ELECTRICALLY-DRIVEN PARTICULATE AGGLOMERATION IN A COMBUSTION SYSTEM**

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(57) **ABSTRACT**

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Technologies are presented for applying electrical energy to a combustion reaction to produce agglomerated combustion particulates. For example, a system may include: one or more electrodes configured to apply electrical energy to a combustion reaction; a combustion zone configured to support the combustion reaction of a fuel at a fuel source; and an electrical power source operatively coupled to the one or more electrodes and configured to apply electrical energy to the combustion reaction. The combustion reaction is controlled to produce a distribution of agglomerated combustion particulates characterized by an increase in at least one of an average particulate diameter or an average particulate mass.

Related U.S. Application Data

(62) Division of application No. 13/849,770, filed on Mar. 25, 2013, now Pat. No. 9,289,780.

(60) Provisional application No. 61/616,223, filed on Mar. 27, 2012, provisional application No. 61/694,212, filed on Aug. 28, 2012.

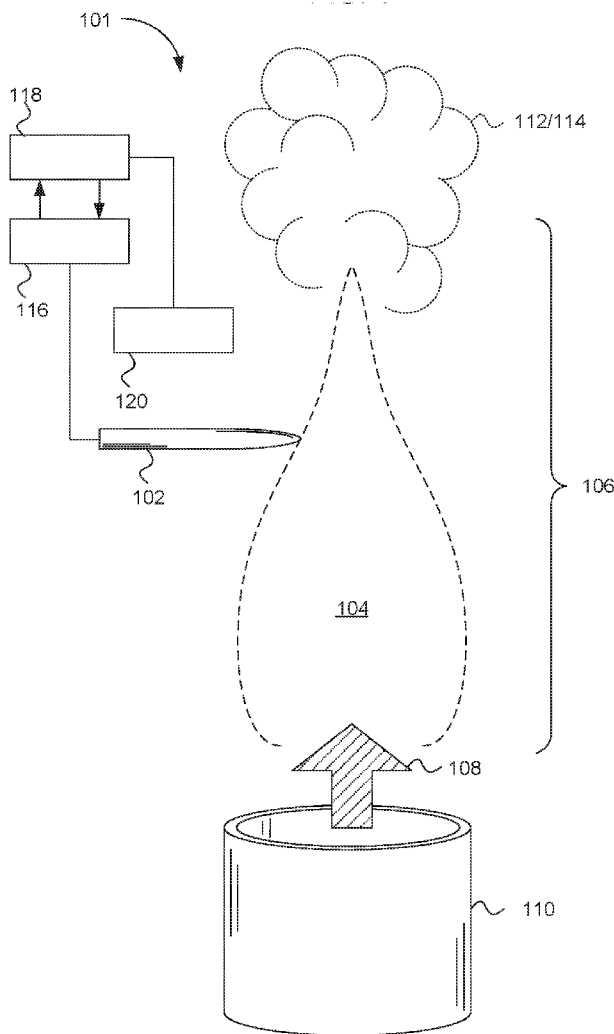


FIG. 1

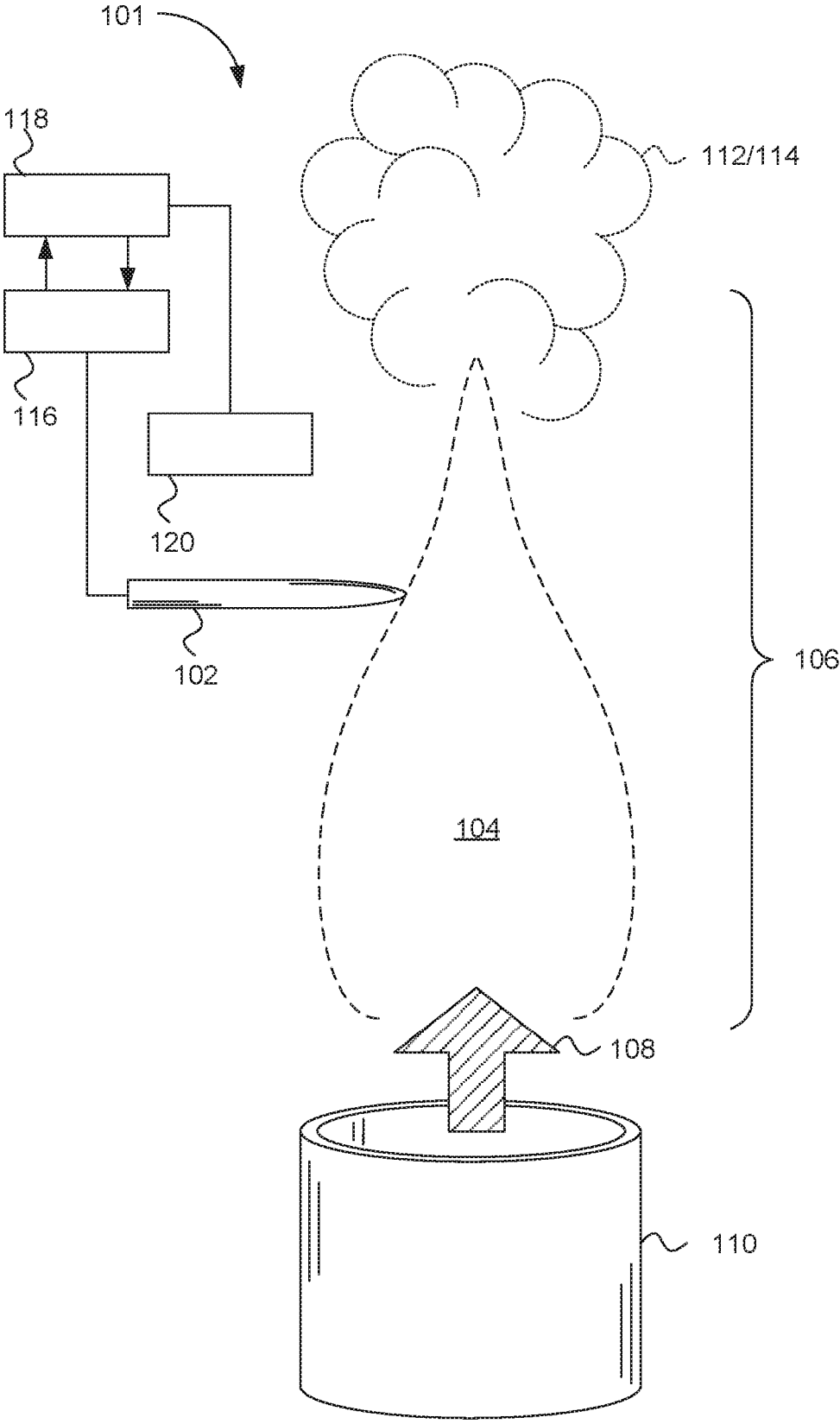


FIG. 2

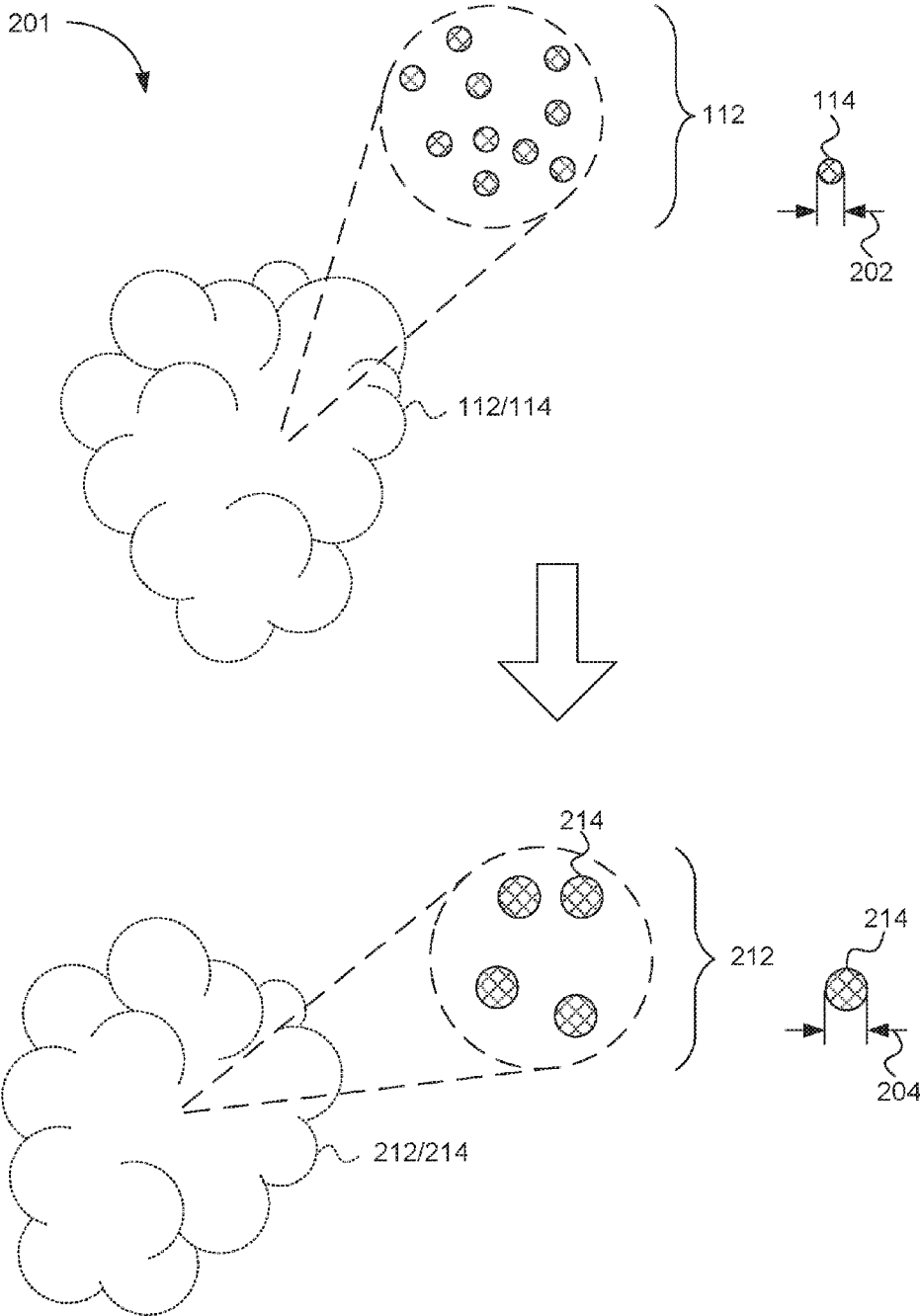


FIG. 3

301

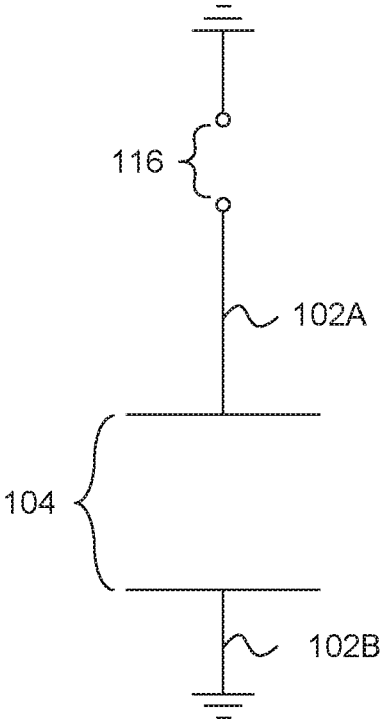



FIG. 4

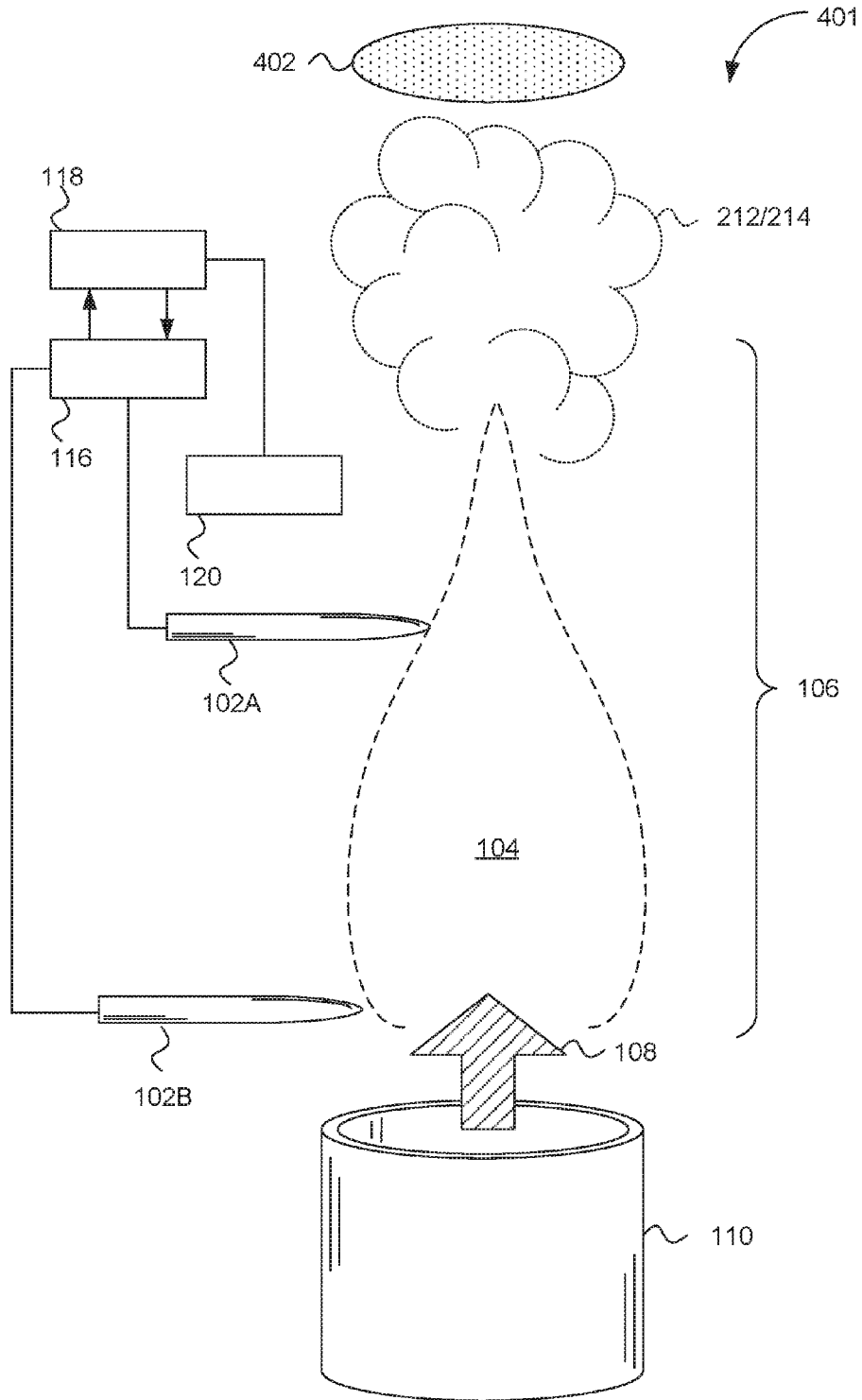


FIG. 5

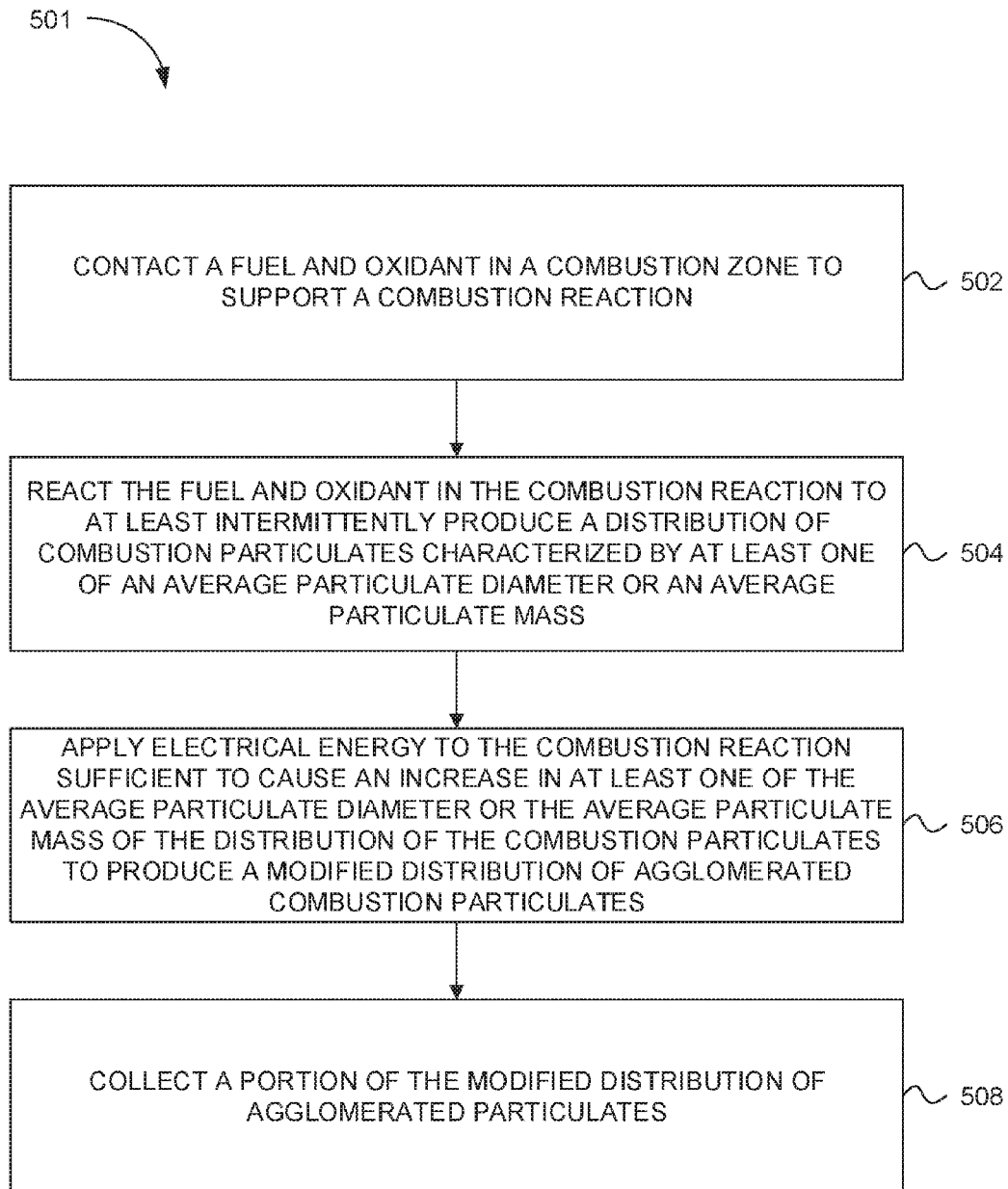
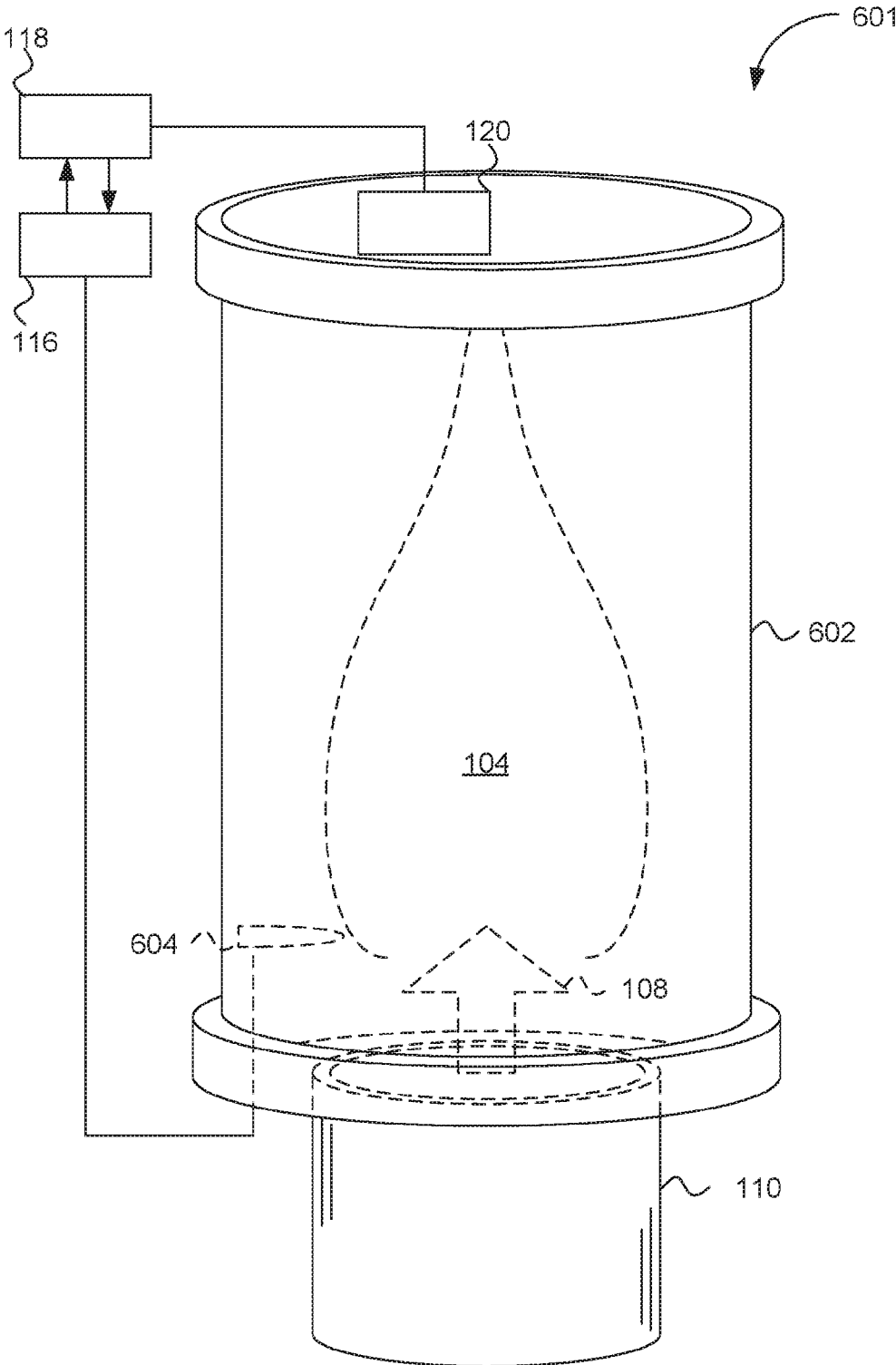


FIG. 6



ELECTRICALLY-DRIVEN PARTICULATE AGGLOMERATION IN A COMBUSTION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority benefit from U.S. Provisional Patent Application No. 61/616,223, entitled "MULTIPLE FUEL COMBUSTION SYSTEM AND METHOD", filed Mar. 27, 2012; and U.S. Provisional Patent Application No. 61/694,212, entitled "ELECTRICALLY-DRIVEN PARTICULATE AGGLOMERATION IN A COMBUSTION SYSTEM", filed Aug. 28, 2012; which, to the extent not inconsistent with the disclosure herein, are incorporated by reference.

BACKGROUND

[0002] Combustion reactions may produce a variety of combustion products, including particulate products. Government regulations impose limits on the amount of particulate pollution that can be released into the atmosphere. It may therefore be necessary to control the amount of particulates produced in a combustion reaction and/or to remove some portion of the particulates from a combustion exhaust stream before it is released.

SUMMARY

[0003] In an embodiment, a system is configured to apply electrical energy to a combustion reaction to produce agglomerated combustion particulates. The system includes at least one electrode, and can include a plurality of electrodes. The electrode is configured to apply electrical energy to a combustion reaction. The system includes a combustion zone. The combustion zone is configured to support the combustion reaction of a fuel at or near a fuel source. The combustion reaction produces a distribution of combustion particulates. The distribution of combustion particulates can be characterized by an average particulate diameter or an average particulate mass. The system also includes an electrical power source. The electrical power source is operatively coupled to the electrode. The electrical power source is configured to apply electrical energy, via the electrode, to the combustion reaction. The electrical energy applied via the electrode to the combustion reaction is controlled to be sufficient to cause an increase in the average particulate diameter or in the average particulate mass of the combustion particulates. The increase in average particulate diameter or average particulate mass of the combustion particulates produces a modified distribution of agglomerated combustion particulates.

[0004] According to an embodiment, the system includes first and second electrodes, and is configured to form an electrical circuit through the combustion reaction.

[0005] According to an embodiment, a method of agglomerating particulates in a combustion reaction is provided. The method includes contacting a fuel and an oxidant in a combustion zone to support a combustion reaction, which produces a distribution of combustion particulates. The method also includes applying electrical energy to the combustion reaction sufficient to cause agglomeration of the combustion particulates.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a block diagram of a system configured to apply electrical energy to a combustion reaction to produce agglomerated combustion particulates, according to an embodiment.

[0007] FIG. 2 is a conceptual scheme illustrating a distribution of combustion particulates characterized by an average particulate diameter and a modified distribution of agglomerated combustion particulates characterized by a modified average particulate diameter, according to an embodiment.

[0008] FIG. 3 is a conceptual schematic of a circuit, including a first electrode, a second electrode, an electrical power supply, and the combustion reaction, according to an embodiment.

[0009] FIG. 4 is a block diagram of a system configured to apply electrical energy to a combustion reaction to produce agglomerated combustion particulates, further including a particulate separation device, according to an embodiment.

[0010] FIG. 5 is a flow diagram of a method of agglomerating particulates in a combustion reaction, according to an embodiment.

[0011] FIG. 6 is a block diagram of a system configured to apply electrical energy to a combustion reaction to produce agglomerated combustion particulates, further including a housing, according to an embodiment.

DETAILED DESCRIPTION

[0012] 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. Other embodiments may be used and/or other changes may be made without departing from the spirit or scope of the disclosure.

[0013] The inventor has recognized that removing particulates from a combustion exhaust stream can be difficult. Many are of such small size that collecting the particles by filtering or other particulate collection methods is undesirably difficult, expensive, inefficient, etc. According to various embodiments, systems and methods are provided in which the combustion particulates produced in combustion reactions are made to agglomerate into larger clusters, i.e., agglomerated particulates. According to some embodiments, the larger agglomerated particulates can be removed from an exhaust stream more easily and with less expense than typical combustion particulates. According to other embodiments, the agglomerated particulates can be removed from an exhaust stream with lower pressure drop (e.g., expressed as reduced back pressure), with higher removal efficiency, and/or with reduced loss of thermodynamic efficiency. Furthermore, because they are larger and more massive, agglomerated particulates that may remain in the exhaust stream fall out of the atmosphere more quickly, and thus have a lower impact on air quality.

[0014] In tests, it was found that combustion particles can be made to agglomerate when the combustion reaction is energized by an electrical source. In particular, the inventor found that a number of different types of signals can be applied to promote agglomeration. With regard to DC-type signals, a positive-polarity signal applied to the combustion reaction can be more effective than a negative polarity signal. Regarding periodic signals, a signal that alternates polarity can be used, as can a signal that does not change polarity,

i.e., a signal with a DC offset. In general, frequencies of between about 50 Hz and 1000 Hz are effective, with the strongest agglomeration being achieved at frequencies between about 200 Hz and 300 Hz. Results are also stronger at higher signal voltage levels. On the other hand, current levels, and thus power consumption, are very low. Typically, the signal voltage should be above 1000 V, and can exceed 40,000 V.

[0015] These values can vary according to various of factors, such as, for example, the type, size, and temperature of the combustion reaction, the configuration of the space in which the combustion occurs, the formulations of the fuel and oxidizer, the ambient temperature, humidity, etc.

[0016] It is theorized that the agglomeration is caused by an increase in effective particle diameter responsive to the acceleration of charged particles in the electric field. Collisions between charged and uncharged particles can accelerate the uncharged particles. The increase in effective diameter increases the likelihood that it will come into contact with other such particulates. As particulates of appropriate types contact each other, they tend to adhere, forming agglomerated particles.

[0017] FIG. 1 is a block diagram of a system 101 configured to apply electrical energy to a combustion reaction 104 to produce agglomerated combustion particulates, according to an embodiment. The system 101 includes one or more electrodes 102. The one or more electrodes 102 are configured to apply electrical energy to a combustion reaction 104, for example, by direct contact. The system 101 also includes a combustion zone 106. The combustion zone 106 is configured to support the combustion reaction 104 of a fuel 108 supplied by a fuel source 110. The combustion reaction 104 is capable of producing a distribution 112 of combustion particulates 114. The distribution 112 of the combustion particulates 114 can be characterized by at least one of an average particulate diameter 202 (see FIG. 2) or an average particulate mass. The system 101 also includes an electrical power source 116. The electrical power source 116 is operatively coupled to the one or more electrodes 102. The electrical power source 116 is configured to apply electrical energy via the one or more electrodes 102 to the combustion reaction 104. The electrical energy applied via the one or more electrodes 102 to the combustion reaction 104 is sufficient to cause an increase in at least one of the average particulate diameter 202 or the average particulate mass of the distribution 112 of the combustion particulates 114. The increase in at least one of the average particulate diameter 202 or the average particulate mass of the distribution 112 of the combustion particulates 114 produces a modified distribution 212 of agglomerated combustion particulates 214 (see FIG. 2).

[0018] FIG. 2 is a conceptual scheme 201 illustrating the distribution 112 of the combustion particulates 114 and the average particulate diameter 202. FIG. 2 also illustrates the modified distribution 212 of the agglomerated combustion particulates 214 and the modified average particulate diameter 204.

[0019] Referring again to FIG. 1, in an embodiment, the system 101 also includes the fuel source 110. The fuel source 110 is configured to deliver the fuel 108 in the form of one or more of a gas, a liquid, a solid, or a powdered solid. Additionally or alternatively, the combustion reaction 104 can include a flame. Additionally or alternatively, the combustion reaction 108 can at least intermittently produce the distribution 112 of the combustion particulates 114. Additionally or

alternatively, the distribution 112 of the combustion particulates 114 can be visible or invisible to the human eye.

[0020] In an embodiment, the electrical power source 116 is configured to apply the electrical energy via the one or more electrodes 102 to the combustion reaction 104 sufficient to cause an increase of at least about 50% in the average particulate diameter 202 of the distribution 112 of the combustion particulates 114. The increase of at least about 50% in the average particulate diameter 202 of the distribution 112 of the combustion particulates 114 produces the modified average particulate diameter 204 of the modified distribution 212 of the agglomerated combustion particulates 214. Additionally or alternatively, the average particulate diameter 202 of the distribution 112 of the combustion particulates 114 can also be increased such that the modified average particulate diameter 204 is in a range between about 1 micrometer and about 1 millimeter.

[0021] In an embodiment, the electrical power source 116 is configured to apply the electrical energy via the one or more electrodes 102 to the combustion reaction 104 sufficient to cause an increase of at least about 50% in the average particulate mass of the distribution 112 of the combustion particulates 114. The increase of at least about 50% in the average particulate mass of the distribution 112 of the combustion particulates 114 produces the modified average particulate mass of the modified distribution 212 of the agglomerated combustion particulates 214. Additionally or alternatively, the average particulate mass of the distribution 112 of the combustion particulates 114 can be increased such that the modified average particulate mass is in a range between about 0.1 microgram and about 1 milligram.

[0022] In an embodiment, the system 101 includes a controller 118. The controller 118 is operatively coupled to the electrical power source 116. The controller 118 is configured via machine executable instructions. The machine executable instructions can cause the controller 118 to automatically control the electrical power source 116. The electrical power source 116 is automatically controlled to apply the electrical energy via the one or more electrodes 102 to the combustion reaction 104. The electrical energy is sufficient to cause the increase in at least one of the average particulate diameter 202 or the average particulate mass of the distribution 112 of the combustion particulates 114 to produce the modified distribution 212 of the agglomerated combustion particulates 214.

[0023] In an embodiment, the system 101 may include at least one sensor 120. The at least one sensor is operatively coupled to the controller 118. The controller 118 is configured to detect a sensor value from the at least one sensor 120, for example, configured at least in part according to the machine executable instructions. Additionally or alternatively, the controller 118 can automatically control the electrical power source 116 to apply the electrical energy via the one or more electrodes 102 to the combustion reaction 104 at least in part responsive to the sensor value from the at least one sensor 120.

[0024] In various embodiments, the controller 118 and the at least one sensor 120 are configured to detect the sensor value corresponding to one or more of the following values. The sensor value may correspond to a fuel flow rate. The sensor value may correspond to a temperature. The sensor value may correspond to an oxygen level. The sensor value may correspond to a voltage. The sensor value may correspond to a charge. The sensor value may correspond to a capacitance. The sensor value may correspond to a current.

The sensor value may correspond to a time-varying electrical signal. The sensor value may correspond to a frequency of a periodic electrical signal. The sensor value may correspond to an observed value that correlates to the average particulate diameter. The sensor value may correspond to an observed value that correlates to the average particulate mass. The sensor value may correspond to an observed value that correlates to a density of the distribution of particulates. The sensor value may correspond to an electromagnetic scattering value, for example, a scattering of infrared, visible, or ultraviolet light. The sensor value may correspond to an electromagnetic absorption value, for example, an absorption of infrared, visible, or ultraviolet light. The sensor value may correspond to an electromagnetic emission value, for example, an emission of infrared, visible, or ultraviolet light. In an embodiment, the electrical power source 116 is configured to apply the electrical energy to the combustion reaction 104 by delivering a charge, a voltage, or an electric field through the one or more electrodes 102. For example, the electrical power source 116 is configured to apply the electrical energy to the combustion reaction 104 as a static electrical signal through the one or more electrodes 102. The electrical power source 116 is configured to apply the electrical energy to the one or more electrodes 102 in a voltage range between about +50,000 kilovolts and about -50,000 kilovolts. Additionally or alternatively, the electrical power source 116 is configured to apply the electrical energy to the combustion reaction 104 as a time-varying electrical signal through the one or more electrodes 102. The time-varying electrical signal may include a periodic component. For example, the time-varying electrical signal may include a periodic component characterized by one or more frequencies in a range between about 1 Hertz and about 10,000 Hertz. Additionally or alternatively, the time-varying electrical signal can include an alternating current.

[0025] In an embodiment, the system 101 includes a plurality of electrodes 102 operatively coupled to the electrical power source 116. The electrical power source 116 is configured to drive the plurality of electrodes 102 in a manner similar to that described above with reference to FIG. 1. Another example of a system that employs a plurality of electrodes is described in more detail below, with reference to FIG. 4.

[0026] FIG. 3 is a conceptual schematic of a circuit 301. In an embodiment, the circuit 301 is configured from, for example, the first electrode 102A, the second electrode 102B, the electrical power supply 116, and the combustion reaction 104. The electrical power source 116 is configured to electrically drive the circuit 301. The combustion reaction 104 functions in the circuit 301 at least intermittently as one or more of a resistor, a capacitor, or an inductor.

[0027] FIG. 4 is a block diagram of a system 401. In an embodiment, the system 401 is configured to apply electrical energy to the combustion reaction 104 to produce the agglomerated combustion particulates.

[0028] The system 401 includes a first electrode 102A and a second electrode 102B. The electrical power source 116 is configured to drive the first electrode 102A and the second electrode 102B. In the example shown, the electrical power source 116 is configured to drive the first and second electrodes 102A and 102B, with a time-varying electrical signal in a range between about 1 Hertz and about 1200 Hertz. The electrical power source 116 is configured to drive the first and

second electrodes 102A and 102B, with the voltage in a range between about +15,000 volts and about -15,000 volts.

[0029] The system 401 is configured to form a closed electrical circuit. During operation, the electrical power source 116 drives the circuit, producing an electrical current that passes through the first electrode 102A, the combustion reaction 104, and the second electrode 102B. In some embodiments, the circuit may be intermittent, as action of a flame, for example, opens and closes the circuit.

[0030] The electrical power source 116 and controller 118 can be configured to automatically control parameters of the energy applied to the combustion process to obtain a desired result. For example, where agglomeration of the combustion particulates 214 to produce a smaller number of relatively large particulates is desired, the electrical power source 116 and controller 118 can be configured to control signal frequency and voltage to cause agglomeration of the particulates 214, using feedback from the sensor 120 to determine the optimum values.

[0031] The system 401 may include a particulate separation device 402. The particulate separation device 402 is configured to collect a portion of the modified distribution 212 of the agglomerated combustion particulates 214. Additionally or alternatively, the particulate separation device 402 is configured to collect a portion of the distribution 112 of the combustion particulates 114. Additionally or alternatively, the particulate separation device 402 is configured to collect the modified distribution 212 of the agglomerated combustion particulates 214 preferentially or selectively compared to the distribution 112 of the combustion particulates 114. For example, the portion of the modified distribution 212 of the agglomerated combustion particulates 214 is collected by the particulate separation device 402 according to the increase in the average particulate diameter 202 or the average particulate mass of the distribution 112 of the combustion particulates 114. The portion of the modified distribution 212 of the agglomerated combustion particulates 214 is collected by the particulate separation device 402 according to the modified average particulate diameter 204 or the modified average particulate mass of the modified distribution 212 of the agglomerated combustion particulates 214. The particulate separation device 402 includes one or more of: a filter, a baghouse, a cyclone separator, a baffle separator, a wet scrubber, or an electrostatic precipitator.

[0032] FIG. 5 is a flow diagram of a method 501 of agglomerating particulates in a combustion reaction. In an embodiment, the method 501 includes an operation 502 of contacting a fuel and an oxidant in a combustion zone to support a combustion reaction. The method 501 also includes an operation 504 of reacting the fuel and the oxidant in the combustion reaction to at least intermittently produce a distribution of combustion particulates. The distribution of combustion particulates is characterized by at least one of an average particulate diameter or an average particulate mass. The method 501 also includes an operation 506 of applying electrical energy to the combustion reaction sufficient to cause an increase in at least one of the average particulate diameter or the average particulate mass of the distribution of the combustion particulates to produce a modified distribution of agglomerated combustion particulates. The operation 506 of applying the electrical energy is conducted by an electrical power supply. The electrical power supply is configured to apply the electrical energy via one or more electrodes. The

one or more electrodes are configured to apply the electrical energy from the electrical power supply to the combustion reaction.

[0033] In an embodiment, the method **501** includes providing the fuel in the form of one or more of a gas, a liquid, a solid, or a powdered solid. Additionally or alternatively, the method **501** includes contacting the fuel and the oxidant in the combustion zone to support a flame. Additionally or alternatively, in the method **501**, the distribution of the combustion particulates is visible or invisible to the human eye.

[0034] In an embodiment, the method **501** includes applying the electrical energy to the combustion reaction sufficient to cause an increase of at least about 50% in the average particulate diameter of the distribution of the combustion particulates. The increase of at least about 50% in the average particulate diameter produces a modified average particulate diameter of the modified distribution of the agglomerated combustion particulates. The method **501** also includes increasing the average particulate diameter of the distribution of the combustion particulates such that the modified average particulate diameter is in a range between about 1 micrometer and about 1 millimeter.

[0035] In an embodiment, the method **501** includes applying the electrical energy to the combustion reaction sufficient to cause an increase of at least about 50% in the average particulate mass of the distribution of the combustion particulates. The increase of at least about 50% in the average particulate mass produces a modified average particulate mass of the modified distribution of the agglomerated combustion particulates. The method **501** also includes increasing the average particulate mass of the distribution of the combustion particulates such that the modified average particulate mass is in a range between about 0.1 microgram and about 1 milligram.

[0036] In an embodiment, the method **501** includes automatically applying the electrical energy to the combustion reaction sufficient to cause the increase in at least one of the average particulate diameter or the average particulate mass of the distribution of the combustion particulates to produce the modified distribution of the agglomerated combustion particulates. Automatically applying the energy is accomplished by an automated controller configured by one or more machine executable instructions. The machine executable instructions are typically carried by a non-transitory computer-readable medium. The controller can control the electrical power supply to apply the electrical energy according to the machine executable instructions. The machine executable instructions are configured to carry out one or more operations, actions, or steps described herein.

[0037] In an embodiment, the method **501** includes detecting a sensor value associated with the combustion reaction. Additionally or alternatively, the method **501** also includes automatically applying the electrical energy to the combustion reaction at least in part responsive to the sensor value. The machine executable instructions are configured for operating the controller to automatically detect the sensor value associated with the combustion reaction.

[0038] In various embodiments, the sensor value corresponds to one or more of the following values. The sensor value may correspond to a fuel flow rate. The sensor value may correspond to a temperature. The sensor value may correspond to an oxygen level. The sensor value may correspond to a voltage. The sensor value may correspond to a charge. The sensor value may correspond to a capacitance. The sensor

value may correspond to a current. The sensor value may correspond to a time-varying electrical signal. The sensor value may correspond to a frequency of a periodic electrical signal. The sensor value may correspond to an observed value that correlates to the average particulate diameter. The sensor value may correspond to an observed value that correlates to the average particulate mass. The sensor value may correspond to an observed value that correlates to a density of the distribution of particulates. The sensor value may correspond to an electromagnetic scattering value, for example, a scattering of infrared, visible, or ultraviolet light. The sensor value may correspond to an electromagnetic absorption value, for example, an absorption of infrared, visible, or ultraviolet light. The sensor value may correspond to an electromagnetic emission value, for example, an emission of infrared, visible, or ultraviolet light.

[0039] In an embodiment, the method **501** includes applying the electrical energy by delivering a charge, a voltage, or an electric field to the combustion reaction. The method **501** includes applying the electrical energy to the combustion reaction as a static electrical signal. For example, the method **501** may include applying the electrical energy to the combustion reaction in a voltage range between about +50,000 kilovolts and about -50,000 kilovolts. The method **501** may include applying the electrical energy to the combustion reaction in a voltage range between about +15,000 kilovolts and about -15,000 kilovolts. In an embodiment, the method **501** includes applying the electrical energy to the combustion reaction as a time-varying electrical signal. The time-varying electrical signal may include, for example, an alternating current. The time varying electrical signal may include a periodic component. For example, the time-varying electrical signal may include a periodic component characterized by one or more frequencies in a range between about 1 Hertz and about 10,000 Hertz. In some embodiments, the time-varying electrical signal includes a periodic component characterized by one or more frequencies in a range between about 1 Hertz and about 1200 Hertz.

[0040] In an embodiment, the method **501** includes applying the electrical energy to form a circuit with the combustion reaction. The electrical energy is applied to electrically drive the circuit. The electrical energy may electrically drive the circuit such that the combustion reaction functions in the circuit at least intermittently as one or more of a resistor, a capacitor, or an inductor. The circuit may further include, for example, the one or more electrodes, e.g., a first electrode and a second electrode; and the electrical power supply, operatively coupled to the one or more electrodes; all configured together with the combustion reaction to at least intermittently form the circuit.

[0041] In an embodiment, the method **501** includes an operation **508** of collecting a portion of the modified distribution of the agglomerated combustion particulates, for example, by particulate separation. The operation of collecting the portion of the modified distribution of the agglomerated combustion particulates can proceed according at least in part to the increase in the average particulate diameter or the average particulate mass. Additionally or alternatively, the method **501** includes collecting a portion of the distribution of the combustion particulates. Additionally or alternatively, the operation **508** of collecting the portion of the modified distribution of the agglomerated combustion particulates can proceed preferentially or selectively compared to collecting the portion of the distribution of the combustion particulates. For

example, the portion of the modified distribution of the agglomerated combustion particulates is collected by particulate separation according to the increase in the average particulate diameter or the average particulate mass of the distribution of the combustion particulates. Additionally or alternatively, collecting the portion of the modified distribution of the agglomerated combustion particulates is collected by particulate separation according to the modified average particulate diameter or the modified average particulate mass of the modified distribution of the agglomerated combustion particulates. In an embodiment, the method 501 includes collecting the portion of the modified distribution of the agglomerated combustion particulates by one or more of: filtering, baghouse collecting, cyclonic separating, baffle inertial separating, wet scrubbing, or electrostatic precipitating.

[0042] FIG. 6 is a block diagram of a system 601. The system 601 includes a cylindrical housing 602 that defines lateral dimensions of a combustion zone, within which the combustion reaction occurs. According to an embodiment, at least a portion of the housing 602 is conductive, and functions as a first electrode. A second electrode 604 is positioned inside the housing 602, and is electrically isolated from the housing. The electrical power source 116 is coupled to the housing 602 and second electrode 604, and is configured to apply electrical energy to the combustion reaction 104 substantially as described above, in particular, with reference to the embodiment of FIG. 4.

[0043] 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.-26. (canceled)

27. A method, comprising:

supporting a flame by contacting a fuel and an oxidant in a combustion zone; the flame being electrically conductive;

producing combustion particulates by reacting the fuel and the oxidant in the flame; forming an electrical circuit by putting a first electrode and a second electrode into at least intermittent electrical contact with the flame;

producing agglomerated combustion particulates by applying electrical energy to the flame via the electrical circuit, the electrical energy being sufficient to cause agglomeration of the combustion particulates produced by the flame;

detecting a sensor value that corresponds to an agglomerated combustion particulate parameter; and

inputting the sensor value to a controller that automatically controls the electrical energy at least in part responsive to the sensor value that corresponds to the agglomerated combustion particulate parameter.

28. The method of claim 27, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes applying sufficient electrical energy to the flame to cause an average particulate diameter of the agglomerated combustion particulates to be at least about 50% greater than an average particulate diameter of the combustion particulates produced by the flame without the application of the electrical energy.

29. The method of claim 28, wherein the step of producing agglomerated combustion particulates includes producing

agglomerated combustion particulates having an average particulate diameter in a range between about 1 micrometer and about 1 millimeter.

30. The method of claim 27, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes applying sufficient electrical energy to the flame to cause an average particulate mass of the agglomerated combustion particulates to be at least about 50% greater than an average particulate mass of the combustion particulates produced by the flame without the application of the electrical energy.

31. The method of claim 30, wherein the step of producing agglomerated combustion particulates includes producing agglomerated combustion particulates having an average particulate mass in a range between about 0.1 microgram and about 1 milligram.

32. The method of claim 27, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes automatically applying the electrical energy to the flame sufficient to cause agglomeration of the combustion particulates produced by the flame.

33. The method of claim 32, further comprising:

detecting a sensor value associated with the flame; and

wherein the step of automatically applying the electrical energy to the flame includes automatically applying the electrical energy to the flame at least in part responsive to the sensor value that is associated with the flame.

34. The method of claim 33, wherein the step of detecting the sensor value associated with the flame includes detecting a sensor value corresponding to one or more of: a fuel flow rate; a temperature; an oxygen level; a voltage;

a charge; a capacitance; a current; an average particulate diameter; an average particulate mass; a density of a distribution of particulates; an electromagnetic scattering value; an electromagnetic absorption value; and an electromagnetic emission value.

35. The method of claim 27, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes applying electrical energy by delivering at least one of a charge, a voltage, and an electric field to the flame.

36. The method of claim 27, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes applying electrical energy to the flame as a substantially constant electrical signal.

37. The method of claim 27, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes applying electrical energy to the flame in a voltage range between about +50,000 kilovolts and about -50,000 kilovolts.

38. The method of claim 37, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes applying electrical energy to the flame in a voltage range between about +15,000 kilovolts and about -15,000 kilovolts.

39. The method of claim 27, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame includes applying electrical energy to the flame as a time-varying electrical signal.

40. The method of claim 39, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame as a time-varying electrical signal includes applying electrical energy to the flame as an alternating current.

41. The method of claim **39**, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame as a time-varying electrical signal includes applying electrical energy to the flame as a time-varying electrical signal having a periodic component.

42. The method of claim **41**, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame as a time-varying electrical signal includes applying electrical energy to the flame as a time-varying electrical signal having a periodic component with a frequency in a range between about 1 Hertz and about 10,000 Hertz.

43. The method of claim **41**, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the flame as a time-varying electrical signal includes applying electrical energy to the flame as a time-varying electrical signal having a periodic component with a frequency in a range between about 1 Hertz and about 1200 Hertz.

44. (canceled)

45. The method of claim **27**, wherein the step of producing agglomerated combustion particulates by applying electrical energy to the circuit includes applying electrical energy to the electrical circuit such that the flame functions in the circuit at least intermittently as one or more of a resistor, a capacitor, and an inductor.

46. The method of claim **27**, further comprising collecting a portion of the agglomerated combustion particulates.

47. The method of claim **46**, wherein the step of collecting a portion of the agglomerated combustion particulates includes collecting the portion of the agglomerated combustion particulates by at least one selected from the group consisting of filtering, baghouse collecting, cyclonic separating, baffle inertial separating, wet scrubbing, and electrostatic precipitating.

48. The method of claim **27**, further comprising putting the first electrode and/or the second electrode into direct contact with the flame.

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