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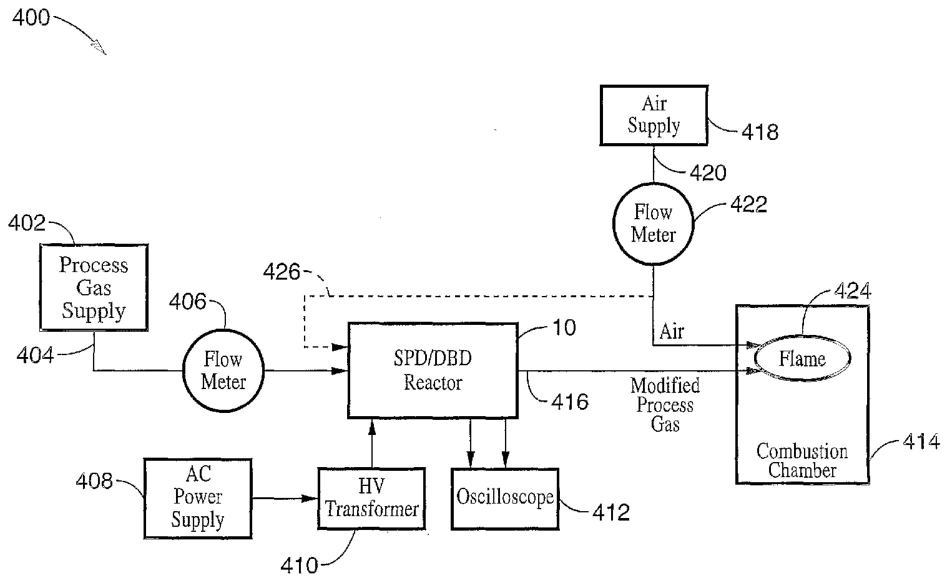
(54) Title: COMBUSTION ENHANCEMENT WITH SILENT DISCHARGE PLASMA



(57) Abstract: A device that uses electrical discharges/nonthermal plasmas in a gaseous medium to activate a fuel or fuel-oxidizer mixture to promote more effective and efficient combustion, in which a dielectric barrier discharge or silent discharge plasma is used to break up larger organic molecules (the fuel) into smaller ones that are more easily and completely combusted. The discharge also creates free radicals that promote more efficient combustion. The device is a cylindrical, coaxial (cylinder in a cylinder) dielectric barrier discharge/silent discharge plasma reactor. It includes two conducting electrodes, one or both of which are covered by a dielectric material. The electrodes are separated by a thin, gas-containing space. A high voltage is applied to the electrodes to create electric discharge streamers in the gas. The discharges are the source of the nonthermal plasma.

WO 2004/085694 A2

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TITLE OF THE INVENTION

COMBUSTION ENHANCEMENT WITH SILENT DISCHARGE PLASMA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with Government support under Contract No. W-7405-ENG-36, awarded by the Department of Energy. The Government has certain rights in this invention.

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

[0003] Not Applicable

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0004] This invention pertains generally to devices for processing combustible gases, and more particularly to non-thermal plasma reactors.

2. Description of Related Art

[0005] To operate fossil-fueled motor vehicles and other combustion-related engines or machinery under higher efficiency and reduced pollution output conditions in the future, it is desirable to have clean-burning, energy-efficient fuel usage. Higher-order hydrocarbons can be broken up, activated, or exposed to active species to achieve greater combustion efficiency. One example of a particular application is the deployment of a controlled-detonation gas-turbine engine (e.g., an aircraft engine).

[0006] Prior-art plasma combustion-enhancement reactors use thermal arcs or microwave radiation to activate fuel or a fuel-oxidizer mixture. These devices are inefficient, tend to consume copious amounts of energy, and have low active species/free radical yields.

[0007] The present invention has recognized these prior art drawbacks, and has provided the below-disclosed solutions to one or more of the prior art deficiencies.

BRIEF SUMMARY OF THE INVENTION

[0008] The present invention is a device that employs electrical discharges/nonthermal plasmas in a gaseous medium to activate or convert a fuel or a fuel-oxidizer mixture to promote more effective and efficient combustion. In nonthermal plasmas, the electrons are "hot", while the ions and neutral species are "cold" - which results in little waste enthalpy being deposited in a process gas stream. This is in direct contrast to thermal plasmas, where the electron, ion, and neutral-species energies are in thermal equilibrium (or "hot") and considerable waste heat is deposited in the process gas. The present invention utilizes a type of electrical discharge called a silent discharge plasma (SDP), or a dielectric barrier discharge (DBD), to break up large organic fuel molecules into smaller molecules that are more easily and completely combusted and to create highly reactive free-radical chemical species that can promote more efficient combustion by their strong oxidizing power or by their ability to promote combustion-sustaining chain reactions or chain reactions that further generate active species.

[0009] In the present invention, a SDP/DBD reactor is applied to gas streams containing organic fuels or fuel/oxidizer mixtures.

[0010] In one aspect of the present invention, a device for processing combustible gases includes a high voltage electrode and a ground electrode that is slightly spaced from the high voltage electrode. A dielectric layer is disposed adjacent to the high voltage electrode between the high voltage electrode and the ground electrode. A gas modification passage is established within the housing between the dielectric layer and the ground electrode. Moreover, a process gas supply provides a process gas to the gas modification passage. The high voltage electrode can be energizable to create nonthermal electrical microdischarges between the high voltage electrode and the ground electrode across the dielectric layer.

[0011] In another aspect of the present invention, a device for processing combustible gases includes a gas modification passage. Moreover, the device includes means for supplying a process gas to the gas modification passage and means for creating nonthermal electrical microdischarges along the length of the gas modification passage. The process gas flows through the nonthermal electrical microdischarge.

[0012] In yet another aspect of the present invention, a device for processing combustible gases includes a cylindrical housing. A metal oxidizer gas supply tube is disposed within the housing. The oxidizer gas supply tube is electrically grounded. Moreover, a first dielectric tube is disposed within the housing around the oxidizer gas supply tube and a gas modification passage is established between the oxidizer gas supply tube and the first dielectric tube. A metal high voltage electrode circumscribes the first dielectric tube. The high voltage electrode is energizable to create nonthermal electrical microdischarges between the high voltage electrode and the oxidizer gas supply tube along the length of the gas modification passage.

[0013] In still another aspect of the present invention, a device for processing combustible gases includes a rectangular box-shaped housing in which a metal, rectangular, plate-shaped ground electrode is disposed. A rectangular, plate-shaped dielectric layer is slightly spaced from the ground electrode and a gas modification passage is established between the ground electrode and the dielectric layer. In this aspect, a metal, rectangular, plate-shaped high voltage electrode is disposed within the housing adjacent to the dielectric layer. The high voltage electrode is energizable to create nonthermal electrical microdischarges between the high voltage electrode and the ground electrode along the length of the gas modification passage.

[0014] In yet still another aspect of the present invention, a method for processing combustible gases includes establishing a gas modification passage that defines a length. Nonthermal electrical microdischarge is created along the length of the gas modification passage. Additionally, a process gas is provided to the gas modification passage such that the process gas flows through the nonthermal electrical microdischarge.

[0015] An object of the present invention is to provide a device that can be used to convert or activate either fuel or fuel-air mixtures.

[0016] Another object of the present invention is to provide a device that can be used to convert or activate a relatively larger volume of fuel or fuel-air mixture.

[0017] Another object of the present invention is to provide a device that can be used in supersonic combustion applications, as well as conventional internal-combustion engine applications.

[0018] Another object of the present invention is to provide a device that can be meshed with internal-combustion engine fuel-injector systems in order to provide a higher proportion of optimally-atomized and activated fuel into a combustion chamber.

[0019] Further aspects of the invention will be brought out in the following portions of the specification, wherein the detailed description is for the purpose of fully disclosing preferred embodiments of the invention without placing limitations thereon.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0020] The invention will be more fully understood by reference to the following drawings which are for illustrative purposes only:

[0021] FIG. 1 is a side plan view of a first embodiment of a silent discharge plasma reactor.

[0022] FIG. 2 is an end view of the first embodiment of the SDP reactor.

[0023] FIG. 3 is a cross-section view of the first embodiment of the SDP reactor taken along line 3-3 in FIG. 2.

[0024] FIG. 4 is a cross-section view of a second embodiment of a SDP reactor.

[0025] FIG. 5 is a cross-section view of a third embodiment of a SDP/DBD reactor.

[0026] FIG. 6 is a cross-section view of a fourth embodiment of a SDP/DBD reactor.

[0027] FIG. 7 is a side plan view of a fifth embodiment of a SDP/DBD reactor.

[0028] FIG. 8 is a cross-section view of the fifth embodiment of the SDP/DBD reactor taken along line 8-8 in FIG. 7.

[0029] FIG. 9 is a cross-section view of a sixth embodiment of a SDP/DBD reactor.

[0030] FIG. 10 is a block diagram of a non-limiting, exemplary combustion system.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Referring more specifically to the drawings, for illustrative purposes the present invention is embodied in the apparatus generally shown in FIG. 1 through FIG. 10. It will be appreciated that each apparatus may vary as to configuration and as to details of the parts, and that the method may vary as to the specific steps and sequence, without departing from the basic concepts as disclosed herein.

[0032] FIGs. 1, 2, and 3 show a first embodiment of a silent discharge plasma/dielectric-barrier discharge (SDP/DBD) reactor according to the present invention, generally designated 10. As shown in FIGs. 1 and 2, the reactor 10 includes a generally cylindrical housing 12 disposed between a generally disk-shaped inlet end cap 14 and a generally disk-shaped outlet end cap 16. FIGs. 1 and 2 show that the end caps 14, 16 can be removably engaged with the housing 10 using plural nuts 18 and plural bolts 20, but it can be appreciated that any other fastening means well known in the art can be used.

[0033] FIG. 3 shows that the reactor 10 includes a metal, generally cylindrical high-voltage (HV) electrode 22 disposed within the housing 12 between the end caps 14, 16. In a preferred embodiment, the HV electrode 22 is connected to an alternating current (AC) source or a pulsed direct current (DC) source. Moreover, a generally cylindrical, dielectric tube 24 is disposed within the HV electrode 22 such that the HV electrode 22 closely surrounds the dielectric tube 24. Preferably, the dielectric tube 24 is made from a dielectric material, e.g., glass, ceramic, etc. As shown in FIG. 3, a metal, generally cylindrical oxidizer gas supply tube 26 is disposed within the dielectric tube 24. It is to be understood that the oxidizer gas supply tube 26 is electrically grounded. It is to be understood that the electrode 22 and the tubes 24, 26 are concentric to each other and are centered on a central axis 28 established by the reactor 10.

[0034] FIG. 3 shows that a gas modification passage 30 is established between the oxidizer gas supply tube 26 and the dielectric tube 24. Also, an oxidizer gas supply passage 32 is established within the oxidizer gas supply tube 26. Moreover, one end of the oxidizer gas supply tube 26 establishes an oxidizer gas inlet 34 and the other end of the oxidizer gas supply tube 26 establishes an oxidizer gas outlet 36. As shown, a modified process gas outlet 38 is established by the outlet end cap 16 and leads from the gas modification passage 30. FIG. 3 further shows that a first “O” ring 40 and a second “O” ring 42 can be used to seal the ends of the dielectric tube 24, e.g., by placing the first “O” ring 40 between the dielectric tube 24 and the inlet end cap 14 and by placing the second “O” ring 42 between the dielectric tube 24 and the outlet end cap 16.

[0035] FIG. 3 further shows that a first “O” ring groove 44 is established in the inlet end cap 14 such that it circumscribes the oxidizer gas supply tube 26 and a third “O” ring 46 is inserted therein to seal the inlet end cap 14 and prevent modified gas from escaping from the reactor 10 at the interface between the oxidizer gas supply tube 26 and the inlet end cap 14.

[0036] It is to be understood that when the HV electrode 22 is energized, nonthermal electrical microdischarges occurs between the dielectric tube 24 and the metal oxidizer gas supply tube 26 which is electrically grounded. The nonthermal electrical microdischarges occur within the gas modification passage 30 and the width of the gas modification passage 30 defines a discharge gap 48. Preferably, the discharge gap 48 is between one and several millimeters (e.g., 1 - 10 mm).

[0037] It is to be understood that as the process gas, e.g., a fuel or a fuel-air mixture, flows through the gas modification passage 30 within the SDP/DBD reactor 10, the nonthermal electrical microdischarges between the HV electrode 22 and the grounded oxidizer gas supply tube 26 across the dielectric tube 24, can generate highly reactive chemical species, e.g., free radicals, in the process gas to yield a modified process gas. The modified process gas can then be fed to an internal combustion engine, furnace, or any other combustion device. The reactive species generated within the gas modification passage 30 can break up large organic fuel molecules into smaller ones that are more easily and completely combusted and can create highly reactive free-radical chemical species that can promote more efficient combustion by their strong oxidizing power or by their ability to promote combustion-sustaining chain reactions or chain reactions that further generate active species.

[0038] Accordingly, the present invention can be used to "convert" combustible fuels. In other words, the present invention can be used to create fragmented, more easily combustible compounds having smaller molecules. Additionally, the present invention can be used to "activate" combustible fuels, i.e., it can be used to create highly reactive free-radical species that are strong oxidizers or combustion chain carriers, which tend to increase combustion efficiency.

[0039] FIG. 4 shows a second embodiment of a SDP/DBD reactor according to the present invention, generally designated 100. As shown in FIG. 4, the reactor 100 is similar in every aspect to the reactor shown in FIGs. 1, 2, and 3 except for the following modifications. First, a wire 102 is wound around the dielectric tube 24 to establish a HV electrode instead of using HV electrode 22. In addition, the oxidizer gas supply tube 104 shown in FIG. 4 is a tube that is formed with at least one oxidizer outlet 106 to allow oxidizer gas to flow through the reactor 100. As shown, oxidizer gas outlet 106 is formed laterally along the oxidizer gas supply tube 104 and connects the oxidizer gas supply passage 34 to the gas modification passage 30. Moreover, a plug 108 is installed at the end of the oxidizer gas supply tube 104.

[0040] FIG. 5 shows a third embodiment of a SDP/DBD reactor according to the present invention, generally designated 150. As shown in FIG. 5, the reactor 150 is similar in every aspect to the reactor shown in FIGs. 1, 2, and 3 except for the following modifications. First, the oxidizer gas supply tube 152 shown in FIG. 5 is a tube that is formed with at least one oxidizer outlet 154 to allow oxidizer gas to flow through the reactor 150. Second, a second dielectric tube 156 circumscribes the oxidizer gas supply tube 152. Accordingly, a gas modification passage 158 is established between the dielectric tubes 24, 156 and nonthermal electrical microdischarges occur between the HV electrode 22 and the grounded oxidizer gas supply tube 152 across the dielectric tubes 24, 156. Moreover, a plug 160 is installed the end of the oxidizer gas supply tube 152.

[0041] FIG. 6 shows a fourth embodiment of a SDP/DBD reactor according to the present invention, generally designated 170. As shown in FIG. 6, the reactor 170 is similar in every aspect to the reactor shown in FIGs. 1, 2, and 3 except for the following modifications. First, a solid cylindrical ground electrode 172 is disposed within the dielectric tube 24 which, in turn, is disposed within the cylindrical HV electrode 22. The gas modification passage 30 is established between the dielectric tube 24 and the ground electrode 172 and nonthermal electrical microdischarges occur between the HV electrode 22 and the ground electrode 172 across the dielectric tube 24. Oxidizer gas flows through an oxidizer gas inlet 174, through the gas modification passage 30, and exits the reactor 170 through an oxidizer gas outlet 176. In this embodiment, oxidizer-activated fuel mixing does not take place at the end of the electrode 172; instead the activated fuel or fuel-oxidizer mixture simply exits the reactor through passage 176 and enters a combustion chamber.

[0042] FIGs. 7 and 8 show a fifth embodiment of a SDP/DBD reactor according to the present invention, generally designated 200. As shown in FIGs. 7 and 8, the reactor 200 includes a generally rectangular housing 202 disposed between a generally flat, rectangular, plate-shaped inlet end cap 204 and a generally flat, rectangular, plate-shaped outlet end cap 206. FIGs. 7 and 8 show that the end caps 204, 206 can be removably engaged with the housing 200 using plural nuts 208 and plural bolts 210, but it can be appreciated that any other fastening means well known in the art can be used.

[0043] FIG. 8 shows that the reactor 200 includes a metal, generally flat, rectangular, plate-shaped high-voltage (HV) electrode 212 disposed within the housing 202 between the end caps 204, 206. Preferably, the HV electrode 212 is connected to an alternating current (AC) source or a pulsed direct current (DC) source. Moreover, a generally flat, rectangular dielectric plate 214 is disposed within the reactor 200 immediately adjacent to the HV electrode 212. Preferably, the dielectric plate 214 is made from a material such as glass, ceramic, etc. As shown in FIG. 8, a metal, generally flat, rectangular, plate-shaped ground electrode 216 is disposed within the reactor 200 such that it is slightly spaced from the dielectric plate 214. It is to be understood that the ground electrode 216 is electrically grounded.

[0044] As shown in FIG. 8, a gas modification passage 218 is established between the ground electrode 216 and the dielectric plate 214. FIG. 8 further shows that the inlet end cap 204 is formed with a process gas inlet 220 that leads to the gas modification passage 218. Also, a modified gas outlet 222 is established by the outlet end cap 206 and leads from the gas modification passage 220.

[0045] It is to be understood that when the HV electrode 212 is energized, nonthermal electrical microdischarges occur between the HV electrode 212 and the ground electrode 216 across the dielectric plate 214. These nonthermal electrical microdischarges occur within the gas modification passage 218 and the width of the gas modification passage 218 defines a discharge gap 224. Preferably, the discharge gap 224 is between one and several millimeters (e.g., 1 - 10 mm). It can be appreciated that as a process gas flows through the gas modification passage 218, it is modified by the nonthermal electrical microdischarges within the gas modification passage 218, as described in detail above.

[0046] Referring now to FIG. 9, a sixth embodiment of a SDP/DBD reactor according to the present invention is shown and is generally designated 300. The reactor 300 shown in FIG. 9 is essentially identical to the reactor shown in FIGs. 7 and 8 with the one exception that a second dielectric plate 302 is disposed within the reactor 300 between the HV electrode 212 and the ground electrode 216. As shown, the second dielectric plate 302 is immediately adjacent to the ground electrode 216.

[0047] Referring now to FIG. 10, a non-limiting, exemplary combustion system is shown and is generally designated 400. FIG. 10 shows that the system 400 includes an SDP/DBD reactor, e.g., the reactor 10 shown in FIGs. 1, 2, and 3 and described in detail above. A process gas supply 402 can be connected to the SDP/DBD reactor 10 via a process gas fluid line 404, e.g., by connecting fluid line 404 to the oxidizer gas inlet 36 (FIG. 3). As shown, a flow meter 406 is installed along the process gas fluid line 404 to monitor the flow of gas to the SDP/DBD reactor 10.

[0048] As further shown in FIG. 10, a power supply 408, e.g., an AC power supply, is connected to the SDP/DBD reactor 10 via a high voltage (HV) transformer 410. Moreover, an oscilloscope 412 is also connected to the SDP/DBD reactor 10 and can be used to monitor the current and voltage of the signal applied to the SDP/DBD reactor 10 that is used to create the nonthermal electrical microdischarges within the gas modification passage 30 (FIG. 3).

[0049] FIG. 10 shows that the SDP/DBD reactor 10 is connected to a combustion chamber 414 by a modified process gas fluid line 416 that provides modified gas to the combustion chamber 414. An air supply 418 provides air to the combustion chamber 414 via an air fluid line 420 and a flow meter 422 installed along fluid line 420 monitors the flow of air to the combustion chamber 414. It can be appreciated that the modified gas from the SDP/DBD reactor 10 and the air from the air supply 418 can be combined within the combustion chamber 414 and ignited to produce a flame 424. It can be appreciated that the air supply 418 can also be connected to the SDP/DBD reactor 10, as indicated by dashed line 426, and the air/process gas mixture can be modified as described in detail above as it flows through the gas modification passage 30 (FIG. 3).

[0050] Although the description above contains many details, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention. Therefore, it will be appreciated that the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present invention is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural, chemical, and functional equivalents to the elements of the above-described preferred embodiment that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device or method to address each and every problem sought to be solved by the present invention, for it to be encompassed by the present claims. Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112, sixth paragraph, unless the element is expressly recited using the phrase "means for."

CLAIMS

What is claimed is:

1. A device for processing combustible gases, comprising:

a high voltage electrode;

a ground electrode slightly spaced from the high voltage electrode;

a dielectric layer disposed adjacent to the high voltage electrode between the high voltage electrode and the ground electrode;

a gas modification passage established within the housing between the dielectric layer and the ground electrode; and

a process gas supply providing a process gas to the gas modification passage.

2. A device as recited in claim 1, wherein the high voltage electrode is energizable to create nonthermal electrical microdischarges between the high voltage electrode and the ground electrode across the dielectric layer.

3. A device as recited in claim 2, wherein the process gas flows through the nonthermal electrical microdischarges.

4. A device as recited in claim 1, wherein the high voltage electrode is cylindrical.

5. A device as recited in claim 4, wherein the ground electrode is established by a metal oxidizer gas supply tube disposed within the high voltage electrode.

5. A device as recited in claim 4, wherein the ground electrode is established solid metal cylinder disposed within the high voltage electrode.

7. A device as recited in claim 5, wherein the dielectric layer is established by a cylindrical dielectric tube, the dielectric tube being circumscribed by the high voltage electrode.

8. A device as recited in claim 7, wherein the high voltage electrode, the dielectric tube, and the oxidizer gas supply tube are concentric to each other.

9. A device as recited in claim 8, wherein the gas modification passage is established between the dielectric tube and the oxidizer gas supply tube.

10. A device as recited in claim 9, further comprising:

a cylindrical dielectric tube circumscribing the oxidizer gas supply tube.

11. A device as recited in claim 1, wherein the high voltage electrode is a metal rectangular plate.

12. A device as recited in claim 11, wherein the ground electrode is a rectangular plate made from a metal, the ground electrode being slightly spaced from the high voltage electrode.

13. A device as recited in claim 12, wherein the dielectric layer is a rectangular plate made from a dielectric material.

14. A device as recited in claim 13, wherein the dielectric layer is a first dielectric layer and the device further comprises:

a second dielectric layer, the second dielectric layer being a rectangular plate, the gas modification passage being established between the first dielectric layer and the second dielectric layer.

15. A device for processing combustible gases, comprising:

a gas modification passage;

means for supplying a process gas to the gas modification passage; and

means for creating nonthermal electrical microdischarge at least partially along the length of the gas modification passage, the process gas flowing through the nonthermal electrical microdischarge.

16. A device as recited in claim 15, wherein the means for creating nonthermal electrical microdischarge comprises:

at least one high voltage electrode;

at least one ground electrode slightly spaced from the high voltage electrode; and

at least one dielectric layer disposed between the high voltage electrode and the ground electrode, the dielectric layer being adjacent to one of: the high voltage electrode or the ground electrode.

17. A device as recited in claim 16, wherein the gas modification passage is established between the high voltage electrode and the ground electrode at least partially along the length of the dielectric layer.

18. A device as recited in claim 17, wherein the high voltage electrode is energizable to create nonthermal electrical microdischarges between the high voltage electrode and the ground electrode across the dielectric layer.

19. A device for processing combustible gases, comprising:

a cylindrical housing;

a metal oxidizer gas supply tube disposed within the housing, the oxidizer gas supply tube being electrically grounded;

a first dielectric tube disposed within the housing around the oxidizer gas supply tube;

a gas modification passage established between the oxidizer gas supply tube and the first dielectric tube; and

a metal high voltage electrode circumscribing the first dielectric tube, the high voltage electrode being energizable to create nonthermal electrical microdischarges between the high voltage electrode and the oxidizer gas supply tube at least partially along the length of the gas modification passage.

20. A device as recited in claim 19, further comprising:

a process gas supply in fluid communication with the gas modification passage, the process gas supply providing process gas to the gas modification passage.

21. A device as recited in claim 20, further comprising:

a combustion chamber in fluid communication with the gas modification passage, the gas modification passage providing a modified gas to the combustion chamber.

22. A device as recited in claim 21, further comprising:

an air supply in fluid communication with: the gas modification passage or the combustion chamber.

23. A device as recited in claim 19, wherein the high voltage electrode is a metal cylinder.

24. A device as recited in claim 19, wherein the high voltage electrode is a wire wound around the first dielectric tube.

25. A device as recited in claim 19, further comprising:

a second dielectric tube circumscribing the oxidizer gas supply tube, the gas modification passage being established between the first dielectric tube and the second dielectric tube.

26. A device for processing combustible gases, comprising:

a rectangular box-shaped housing;

a metal, rectangular, plate-shaped ground electrode disposed within the housing;

a rectangular, plate-shaped first dielectric layer slightly spaced from the ground electrode;

a gas modification passage established between the ground electrode and the dielectric layer; and

a metal, rectangular, plate-shaped high voltage electrode adjacent to the dielectric layer, the high voltage electrode being energizable to create nonthermal electrical microdischarge between the high voltage electrode and the ground electrode at least partially along the length of the gas modification passage.

27. A device as recited in claim 26, further comprising:

a process gas supply in fluid communication with the gas modification passage, the process gas supply providing process gas to the gas modification passage.

28. A device as recited in claim 27, further comprising:

a combustion chamber in fluid communication with the gas modification passage, the gas modification passage providing a modified gas to the combustion chamber.

29. A device as recited in claim 28, further comprising:

an air supply in fluid communication with: the gas modification passage or the combustion chamber.

30. A device as recited in claim 19, further comprising:

a rectangular, plate-shaped second dielectric layer adjacent to the ground electrode, the gas modification passage being established between the first dielectric layer and the second dielectric layer.

31. A method for processing combustible gases, comprising:

establishing a gas modification passage, the gas modification passage defining a length;

creating nonthermal electrical microdischarges at least partially along the length of the gas modification passage; and

providing a process gas to the gas modification passage such that the process gas flows through the nonthermal electrical microdischarges.

32. A method as recited in claim 31, further comprising:

providing a modified process gas to a combustion chamber, the modified process gas resulting from the flow of process gas through the nonthermal electrical microdischarge.

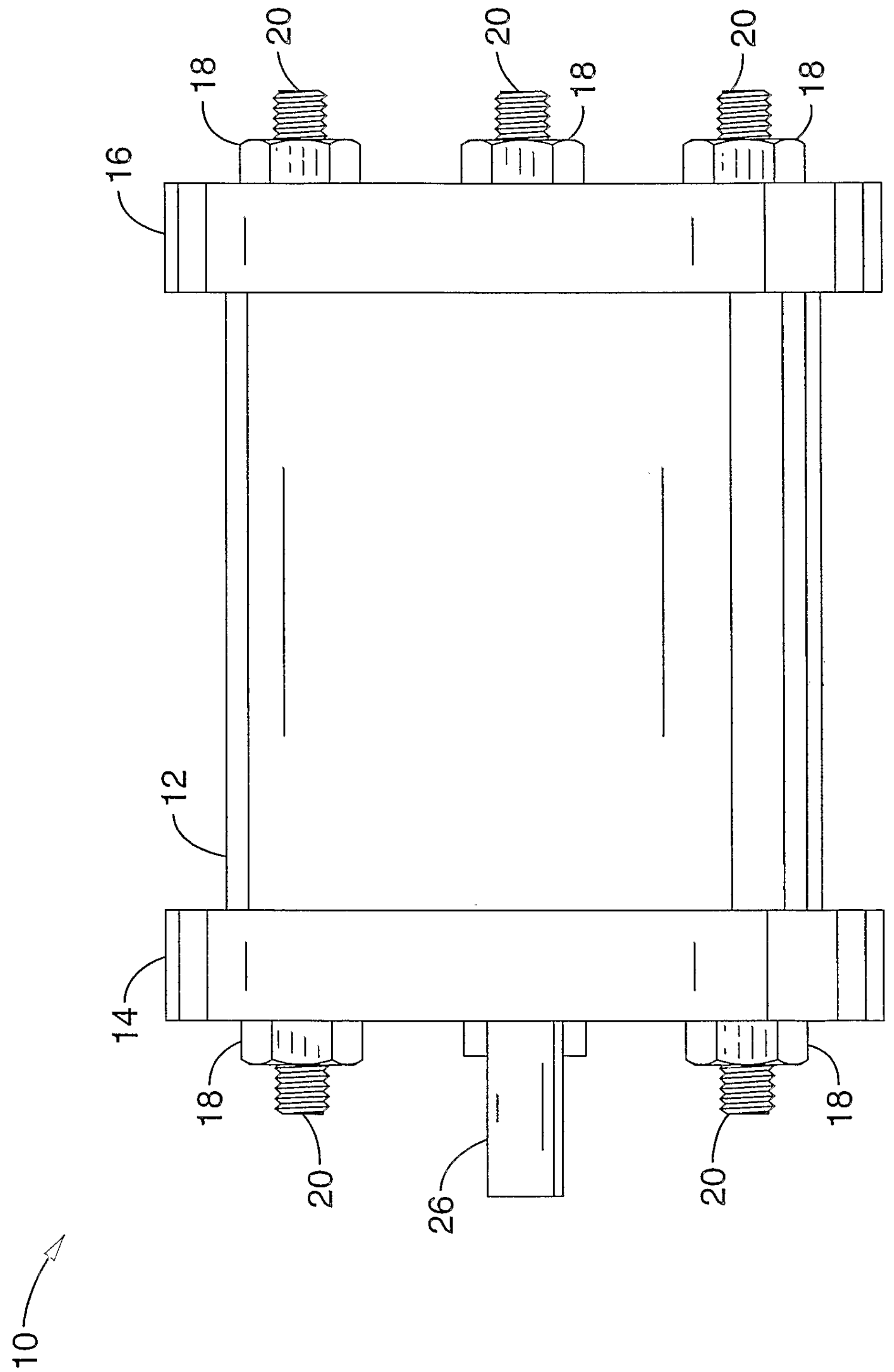


FIG. 1

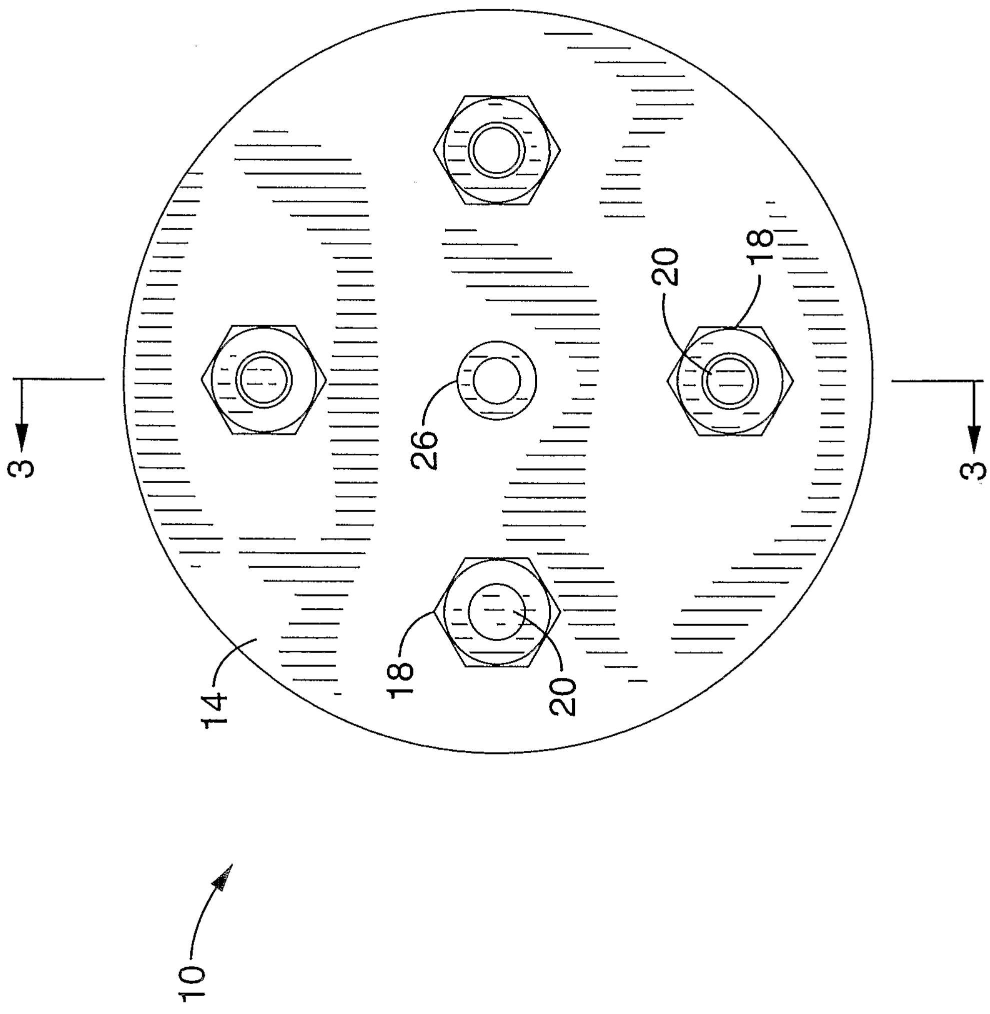


FIG. 2

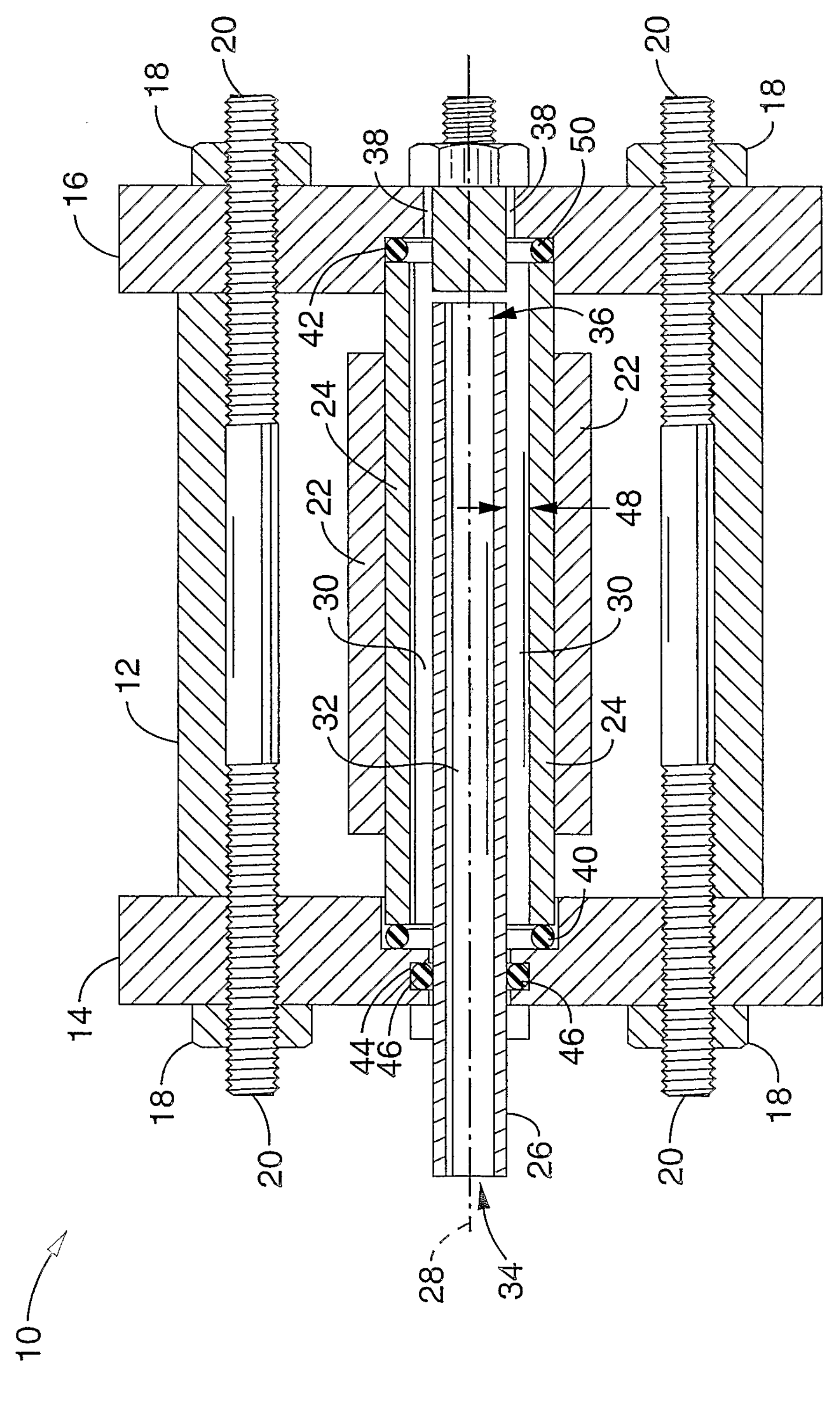


FIG. 3

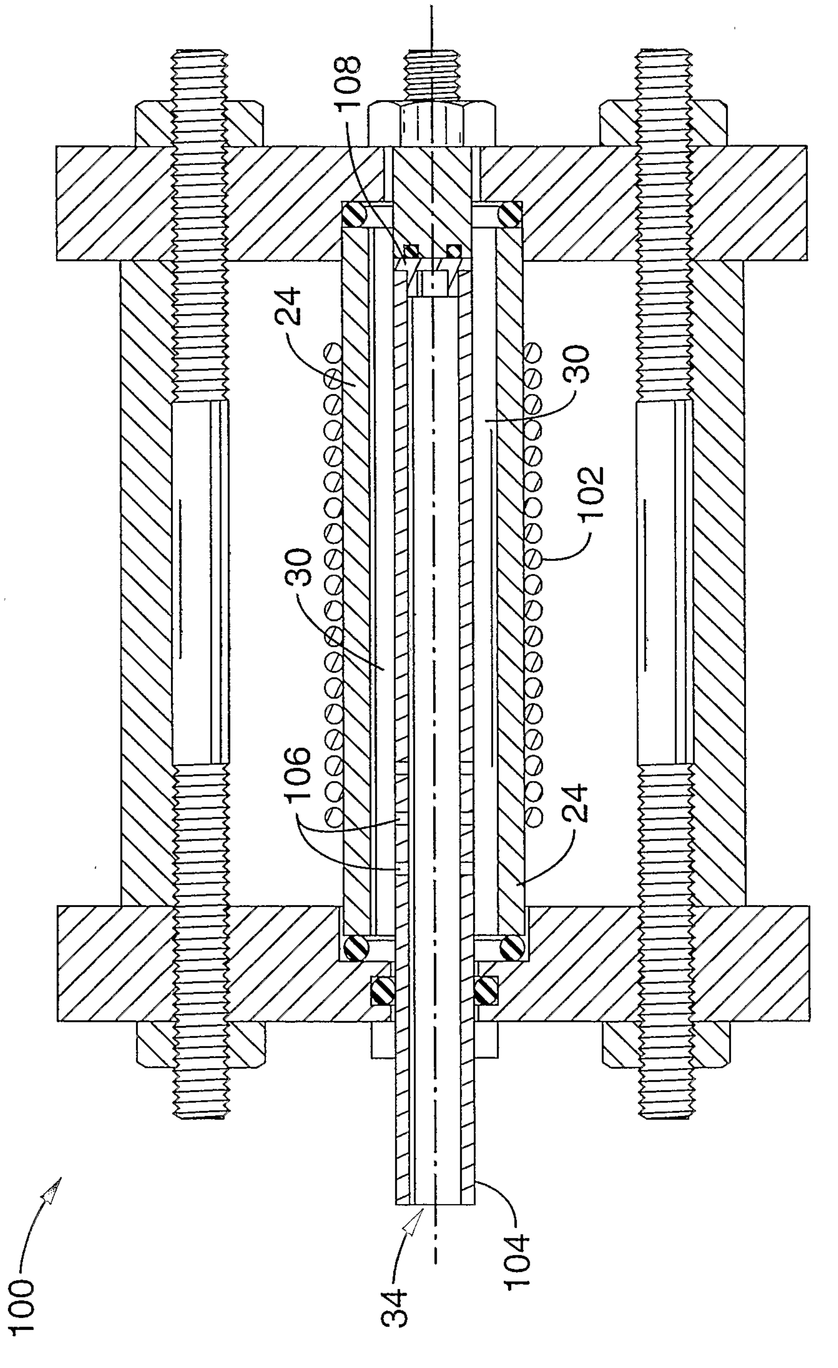


FIG. 4

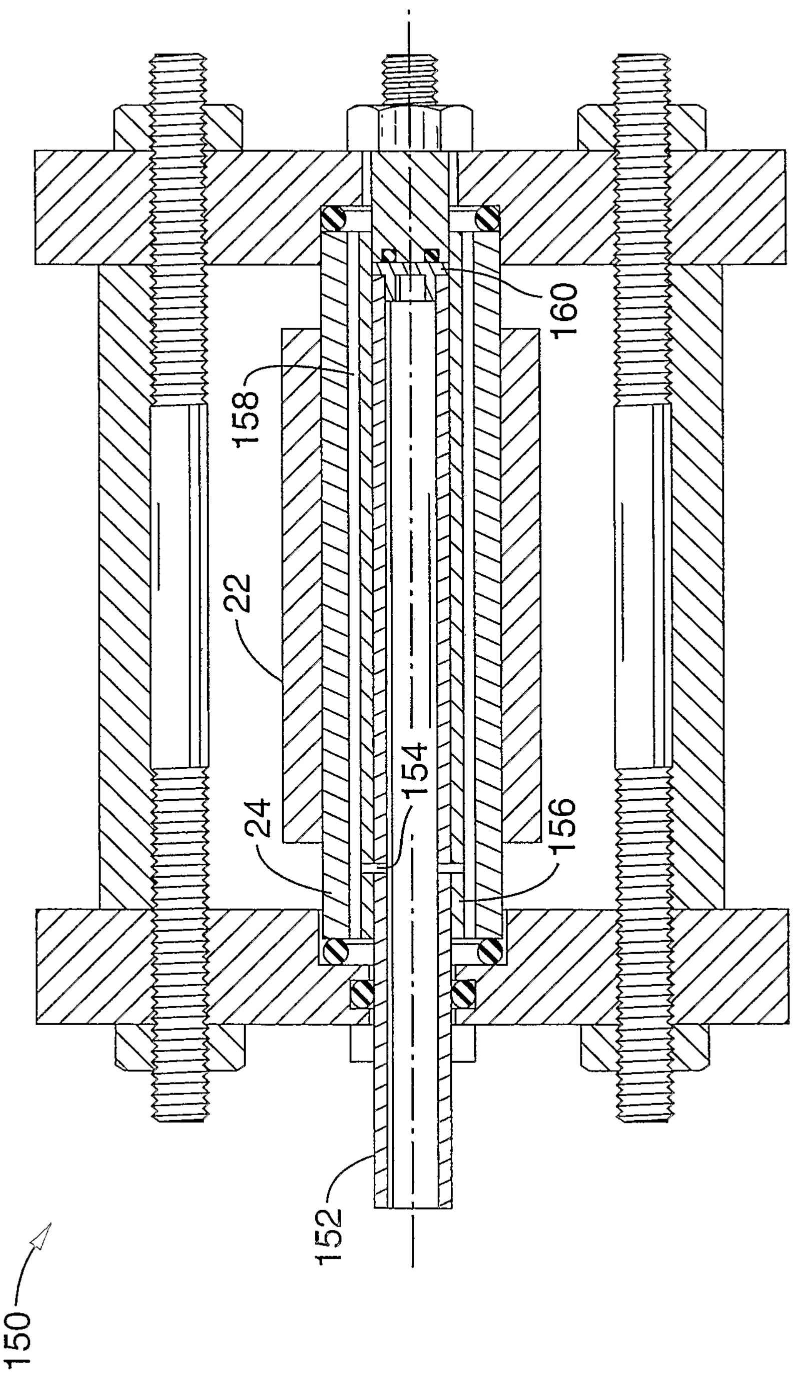
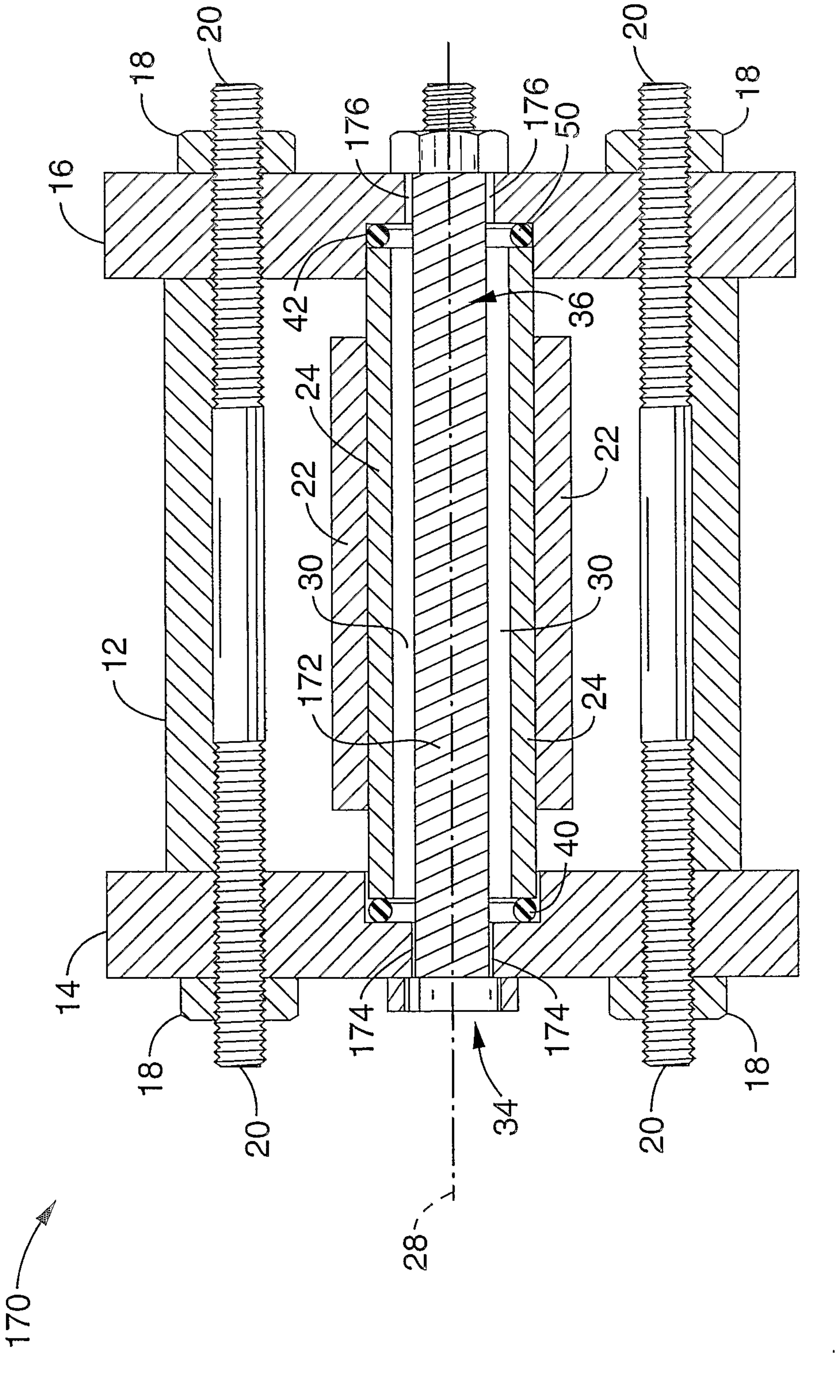


FIG. 5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40
14
174
174
18
20
34
20
18
28
170

FIG. 6

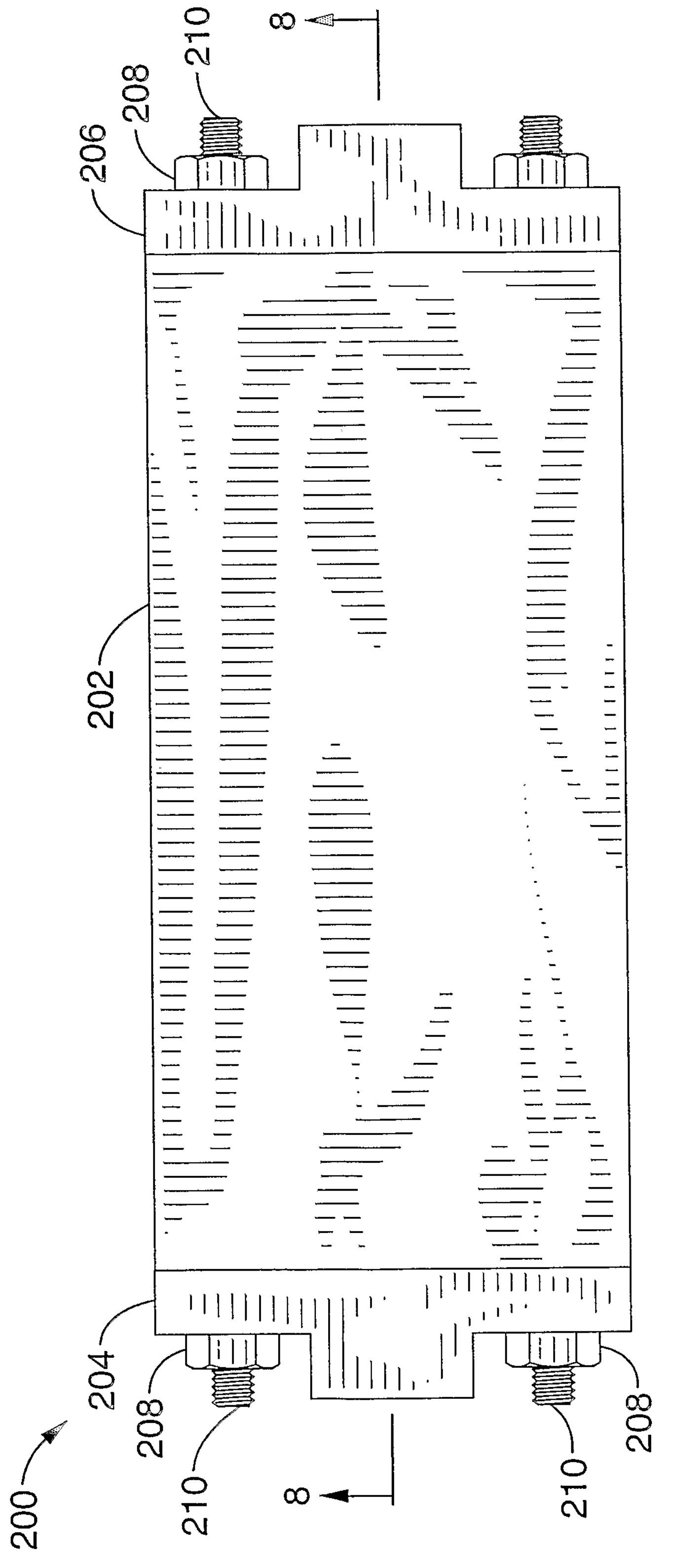

FIG. 7

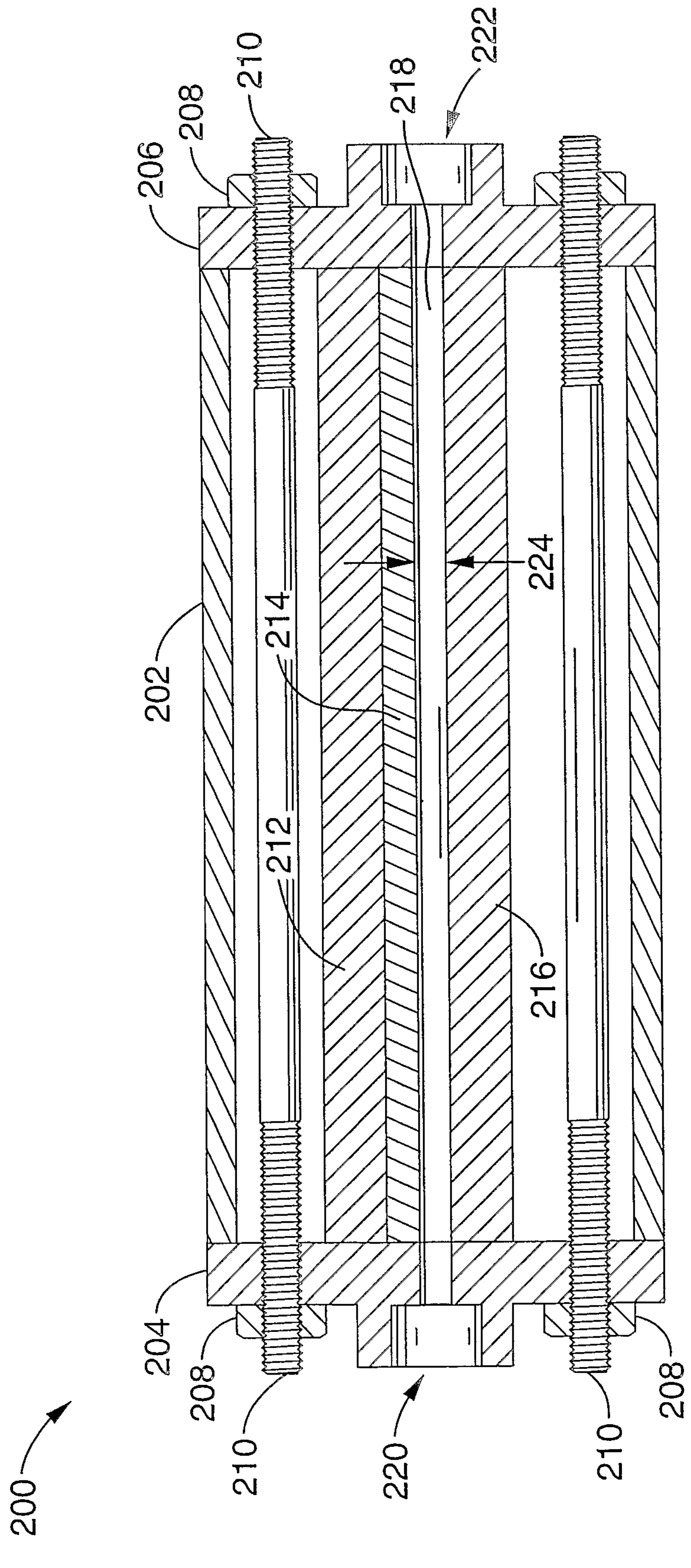

FIG. 8

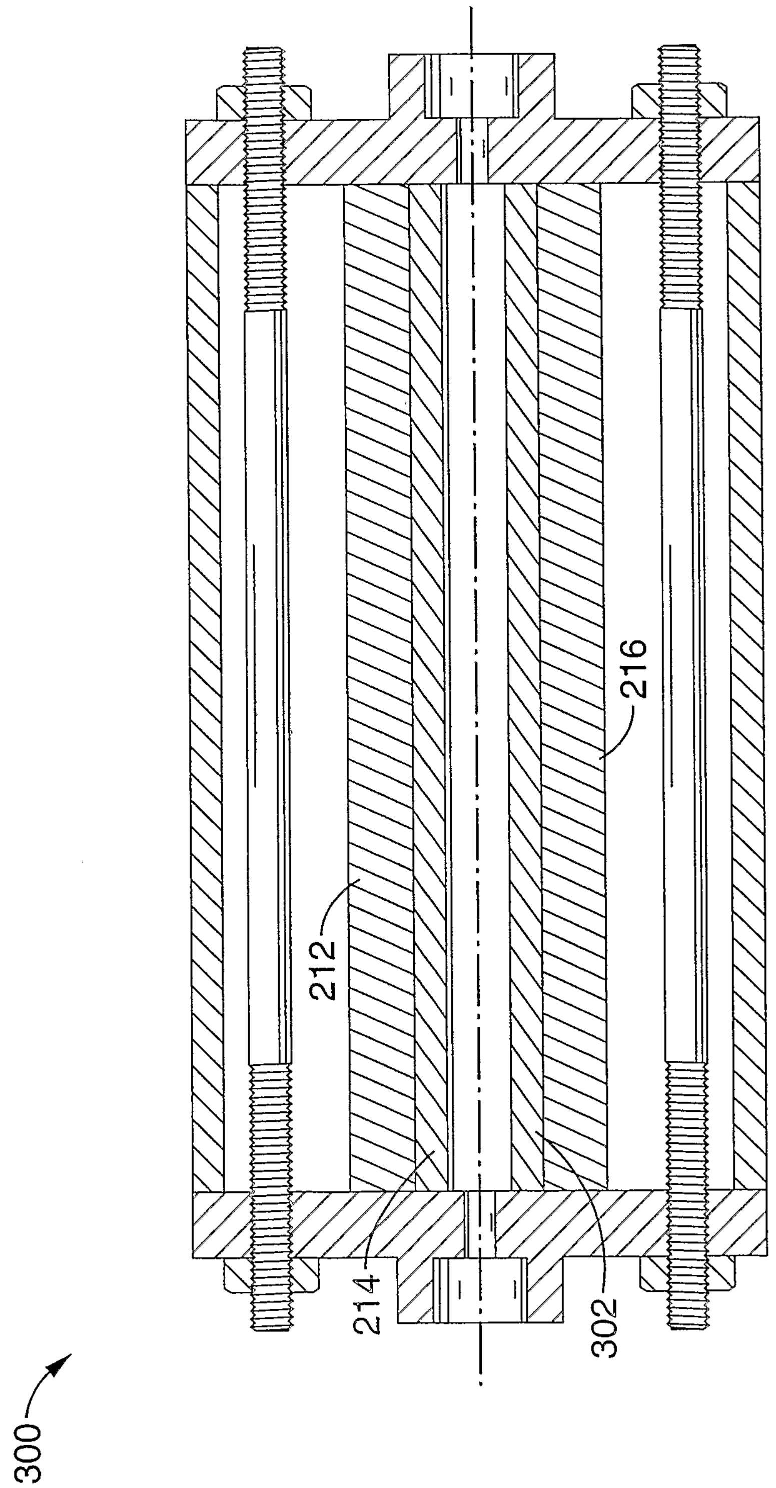

FIG. 9

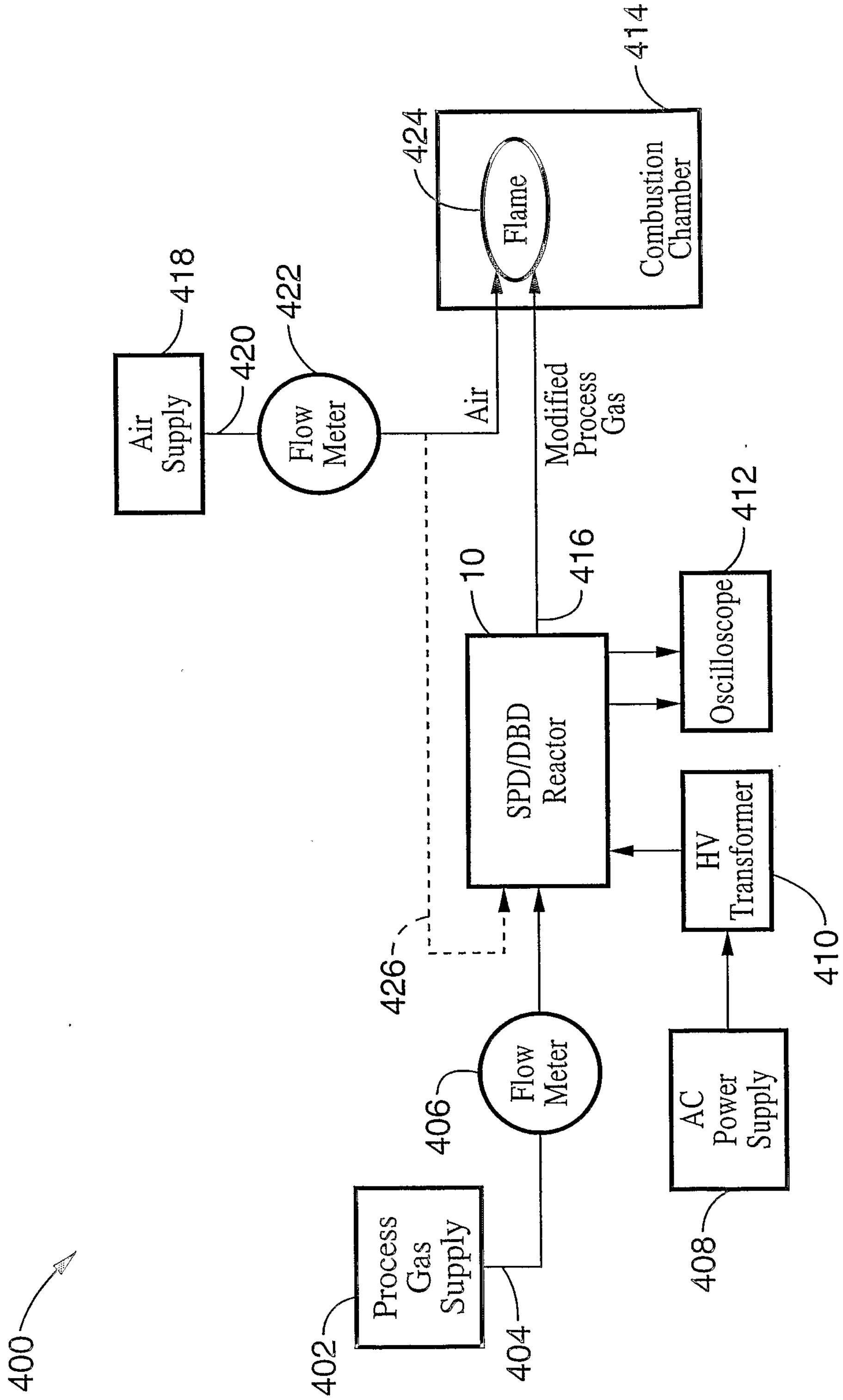
400
Process Gas Supply
402
404
Flow Meter
406
426
SPD/DBD Reactor
10
416
Air Supply
418
420
Flow Meter
422
Air
Modified Process Gas
Flame
424
Combustion Chamber
414
Oscilloscope
412
HV Transformer
410
AC Power Supply
408

FIG. 10