US 20060150614A1

(19) **United States**
(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0150614 A1**
Cummings (43) **Pub. Date: Jul. 13, 2006**

(54) **IONIZING FLUID FLOW ENHANCER FOR COMBUSTION ENGINES**

(76) Inventor: **Craig D. Cummings**, Kamas, OH (US)

Correspondence Address:
DAVID R. MCKINNEY, P.C.
8 EAST BROADWAY, SUITE 500
SALT LAKE CITY, UT 84111 (US)

(21) Appl. No.: **11/366,280**

(22) Filed: **Mar. 2, 2006**

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/035,487, filed on Jan. 15, 2005.

(60) Provisional application No. 60/580,146, filed on Jun. 15, 2004.

Publication Classification

(51) **Int. Cl.**
F01N 3/00 (2006.01)
F02B 35/00 (2006.01)

(52) **U.S. Cl.** **60/275**; 60/315

(57) **ABSTRACT**

An ionizing fluid flow enhancer for a fluid conduit of a combustion engine includes a housing having an inlet configured to receive an inlet flow of fluid; at least one fluid modification element, disposed along the housing, configured to chemically alter the flowing fluid; and a spiral vane assembly, configured to produce an outer helical flow of the fluid and an inner helical flow of the fluid within the housing. The spiral vane assembly includes a plurality of outer vanes, disposed around an outer periphery of the housing, configured to produce an outer helical flow of the fluid; a plurality of inner vanes, disposed within a central portion of the housing, configured to produce an inner helical flow of the fluid, the inner helical flow having a higher velocity than the outer helical flow; and a flow separator, disposed between the inner vanes and the outer vanes, configured to separate the fluid flow into outer flow that flows past the outer vanes, and inner flow that flows past the inner vanes.

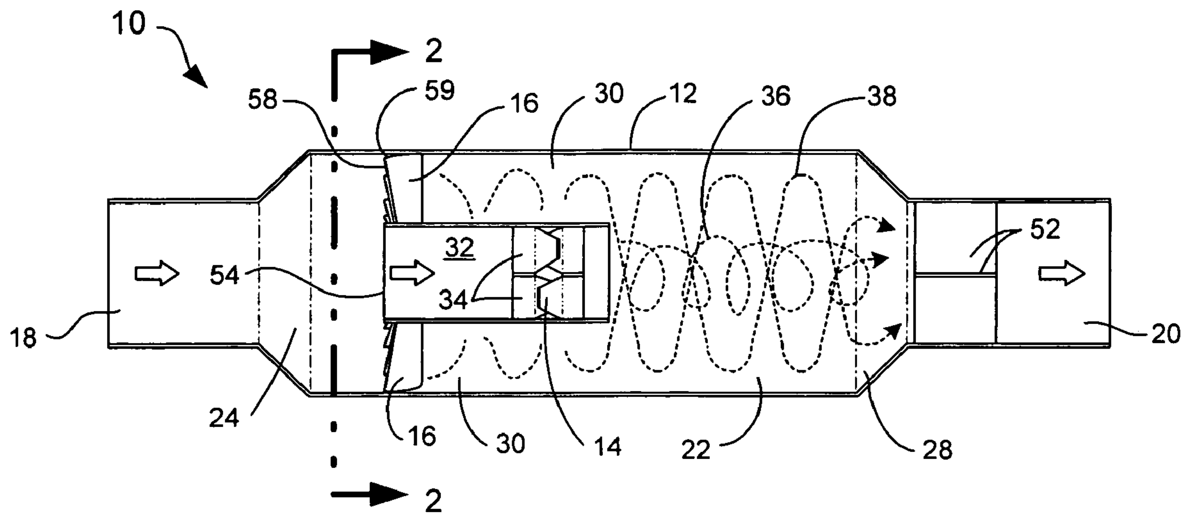


FIG. 1A

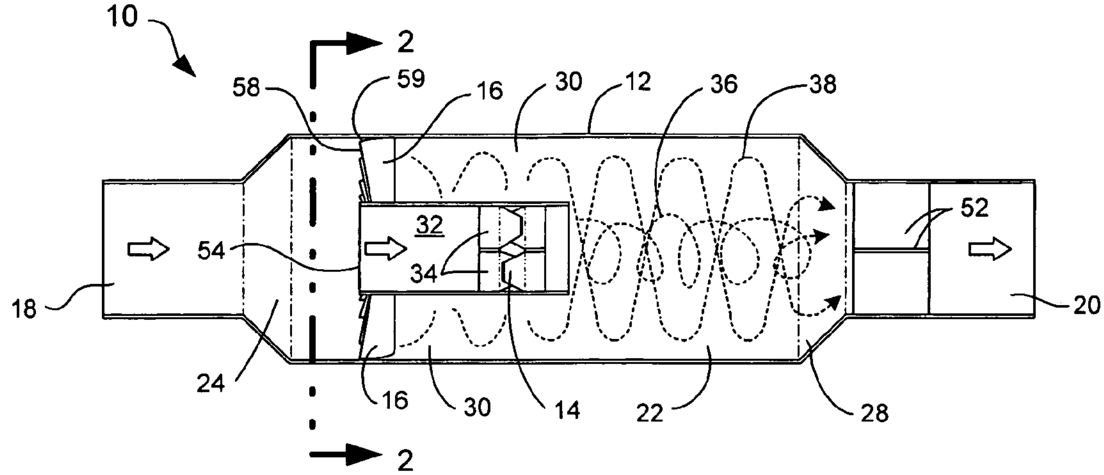


FIG. 1B

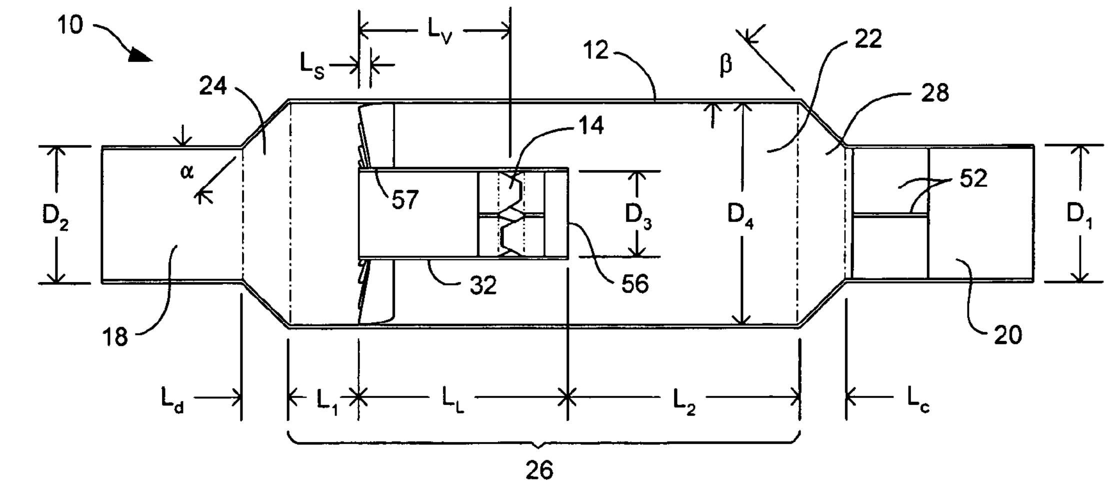


FIG. 2A

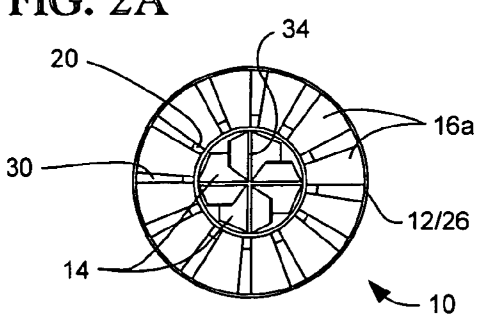


FIG. 2B

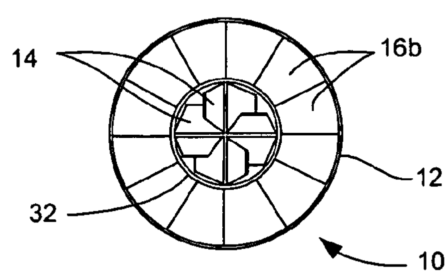
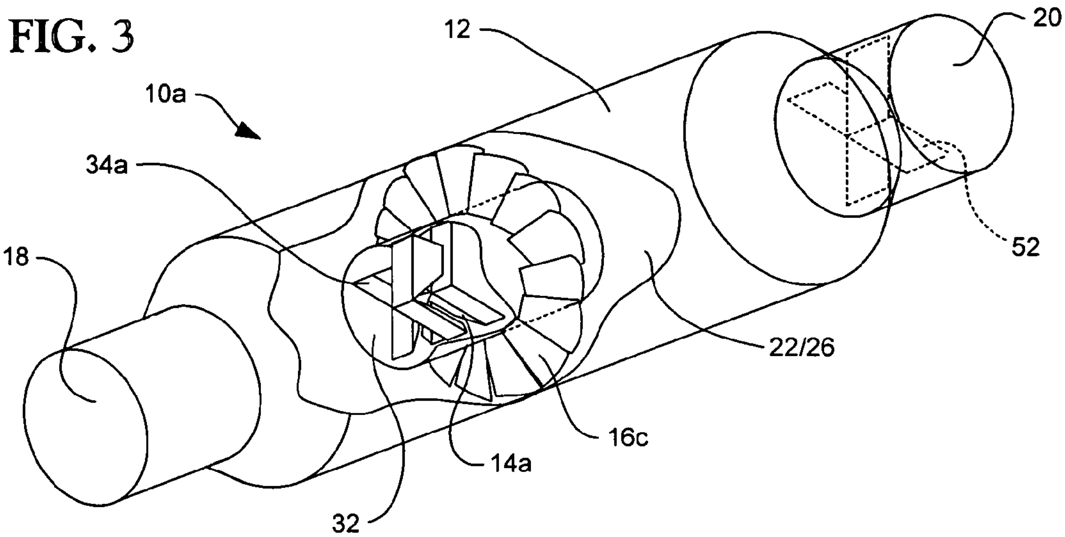
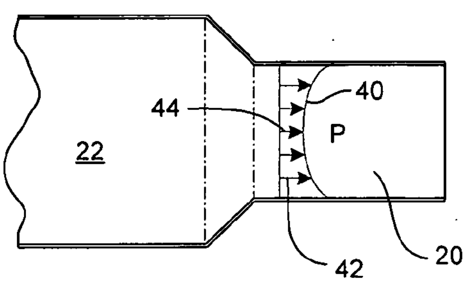


FIG. 3





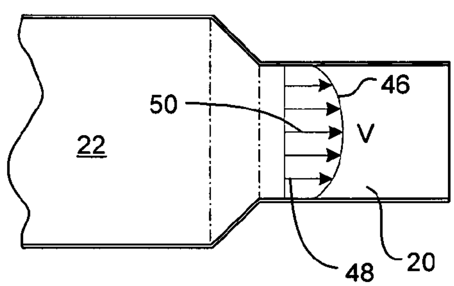


FIG. 4A

FIG. 4B

FIG. 5

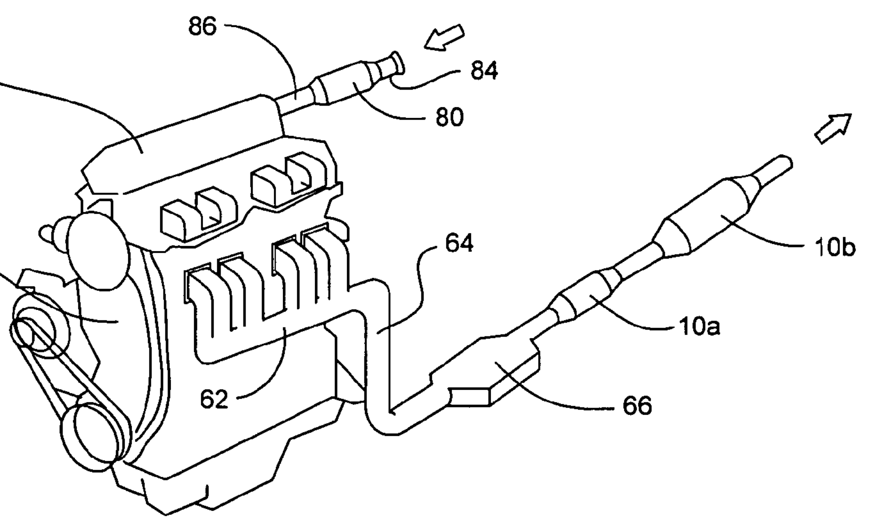


FIG. 6

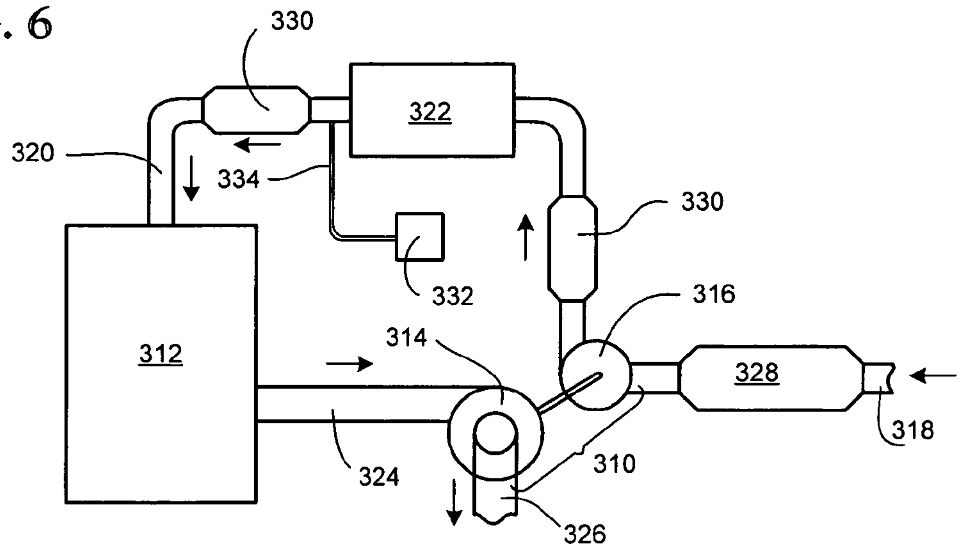


FIG. 7

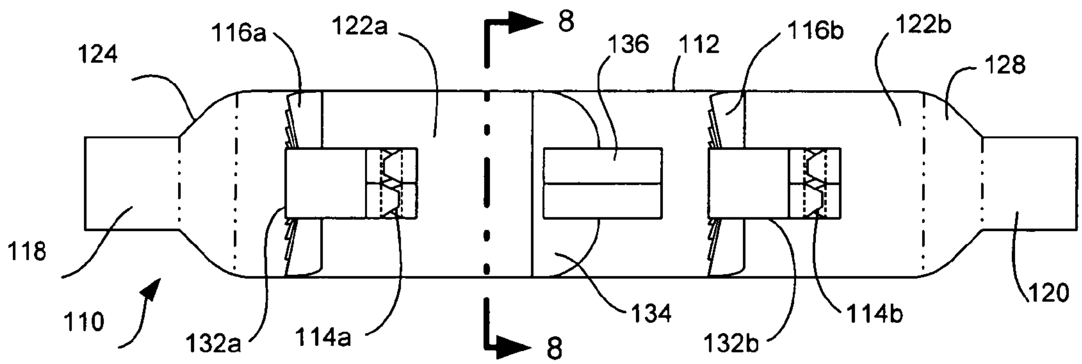


FIG. 8

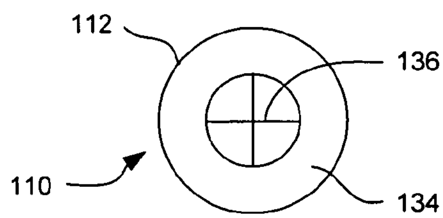


FIG. 9

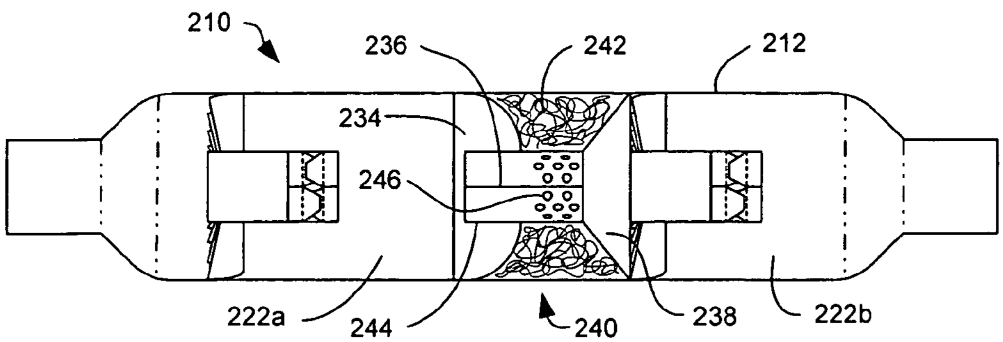


FIG. 10

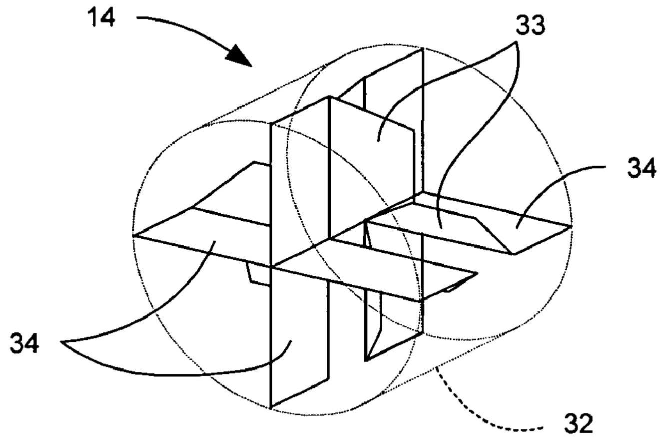


FIG. 11

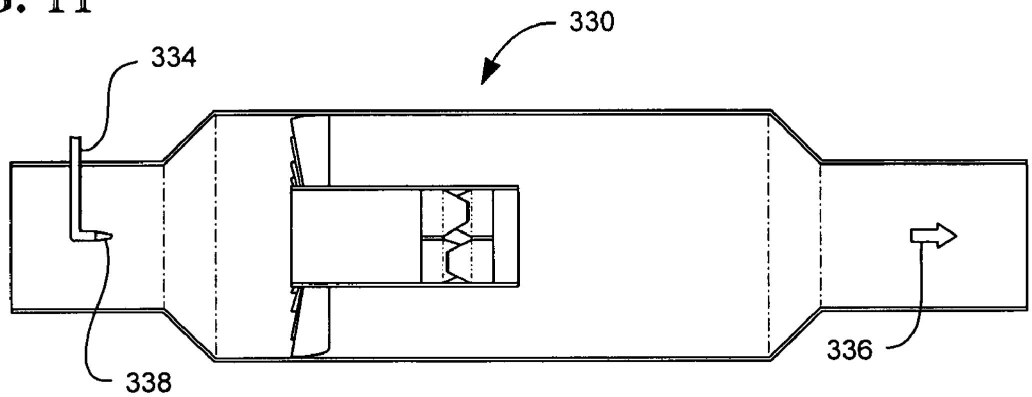


FIG. 12

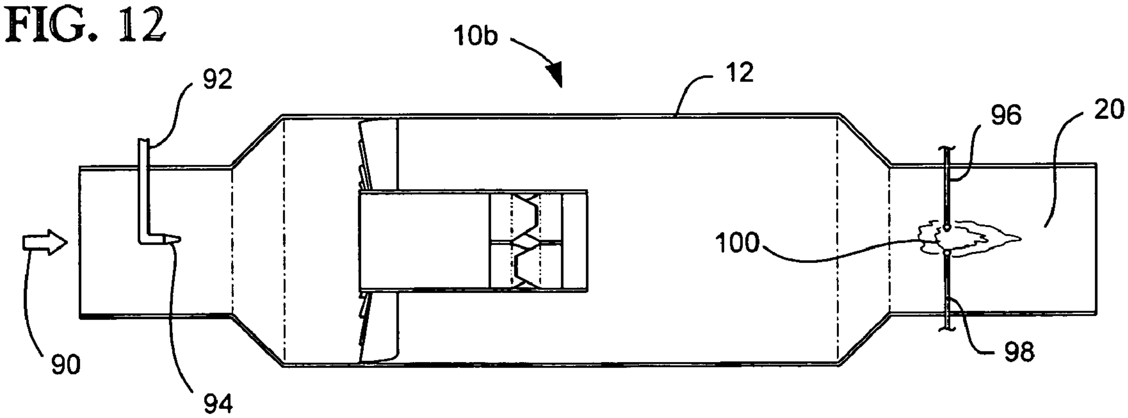


FIG. 13

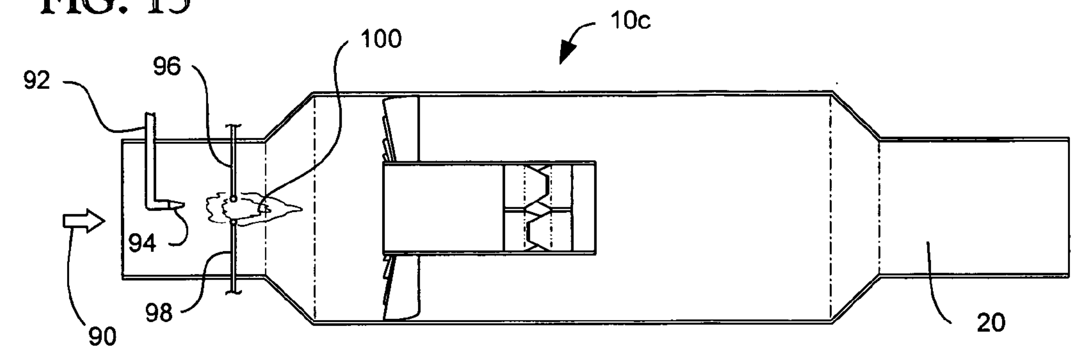


FIG. 14

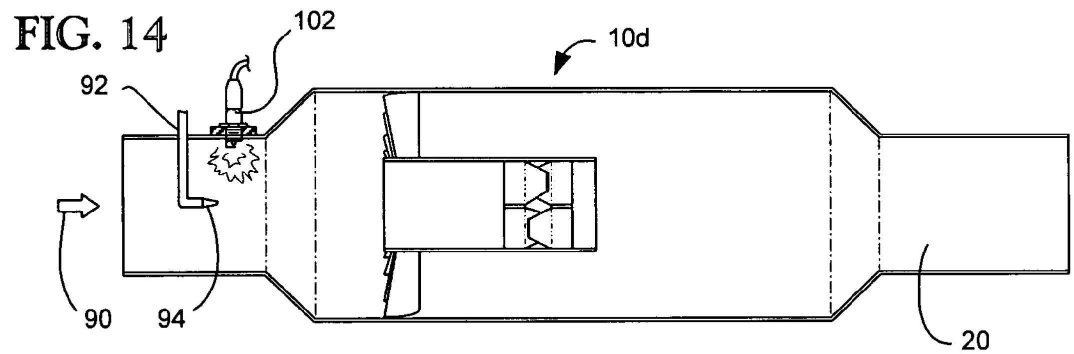


FIG. 15

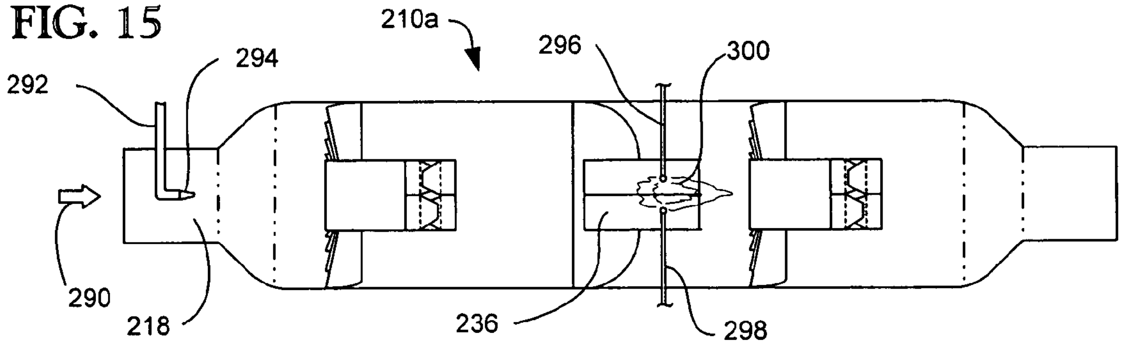


FIG. 16

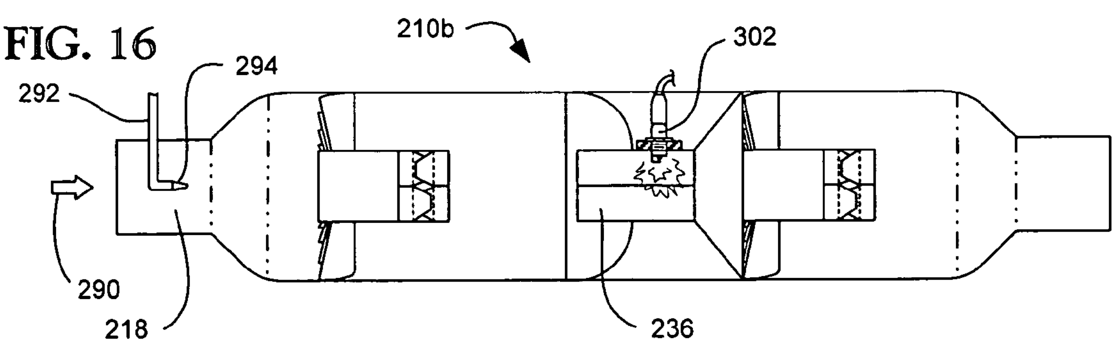


FIG. 17

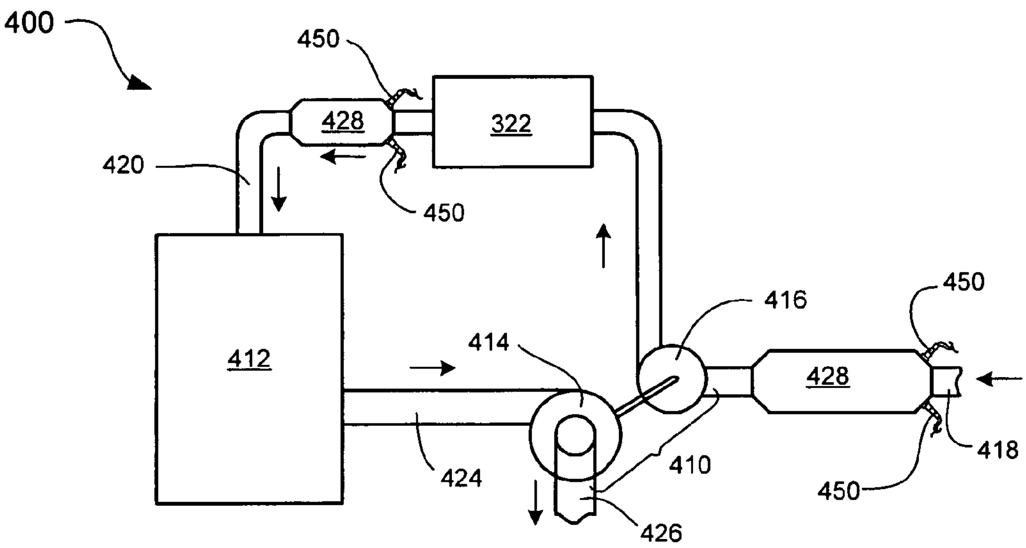


FIG. 18

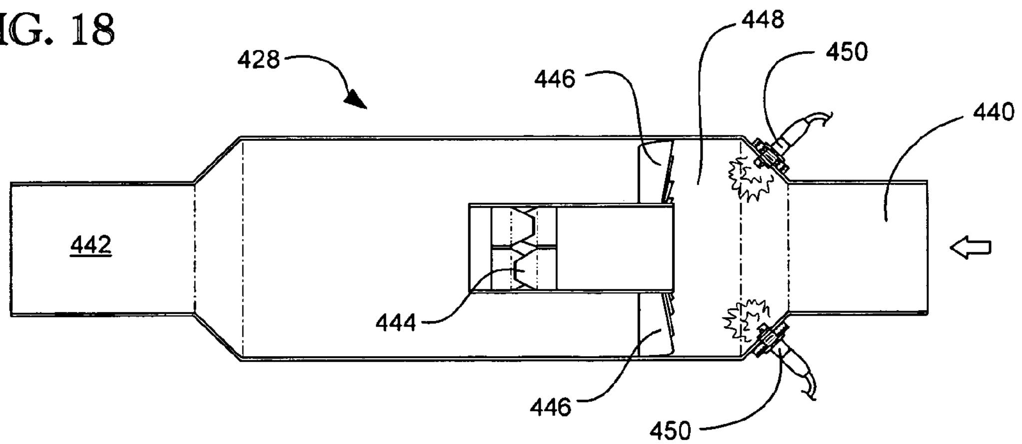


FIG. 19A

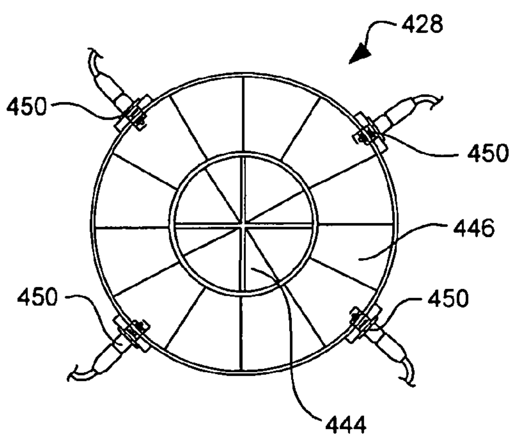


FIG. 19B

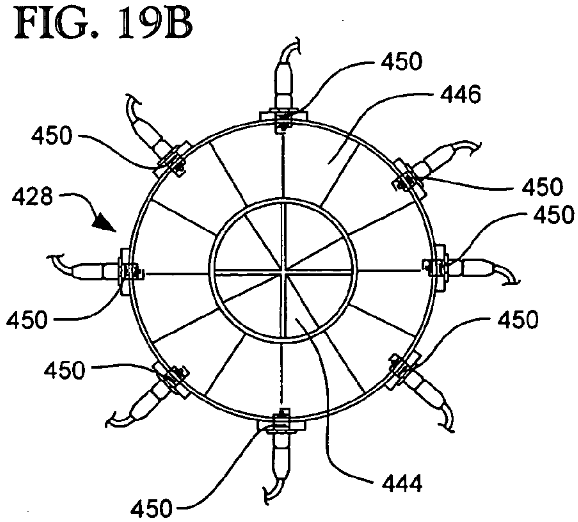


FIG. 20

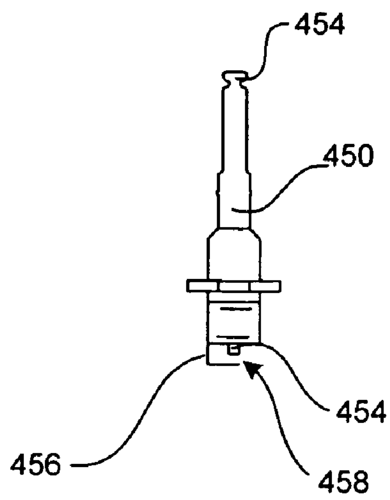
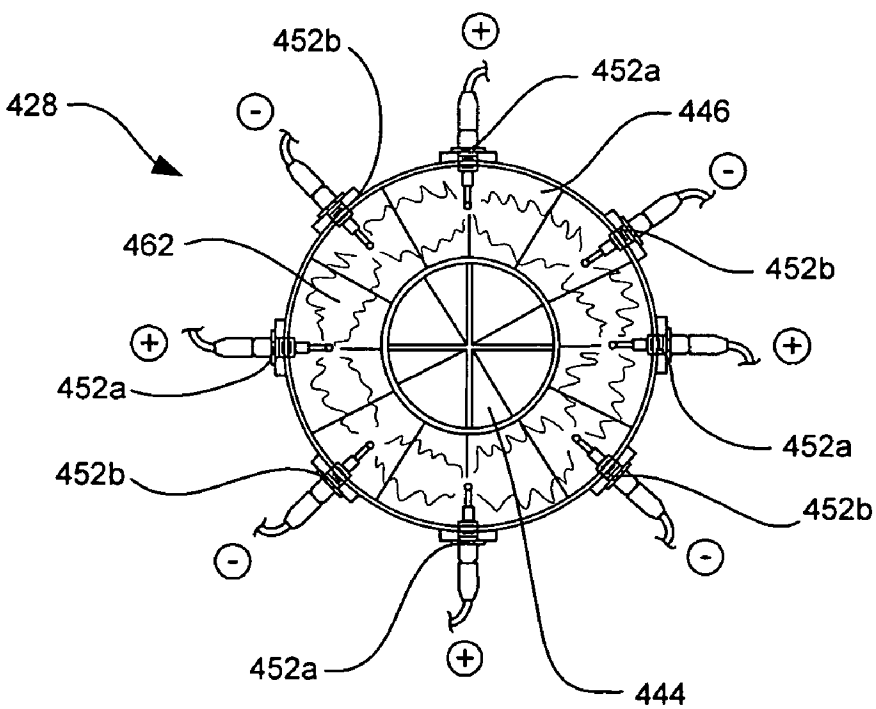

454
450
454
456
458

FIG. 21


428
452b
+
452a
446
-
462
452b
+
452a
452a
452b
452b
452a
444

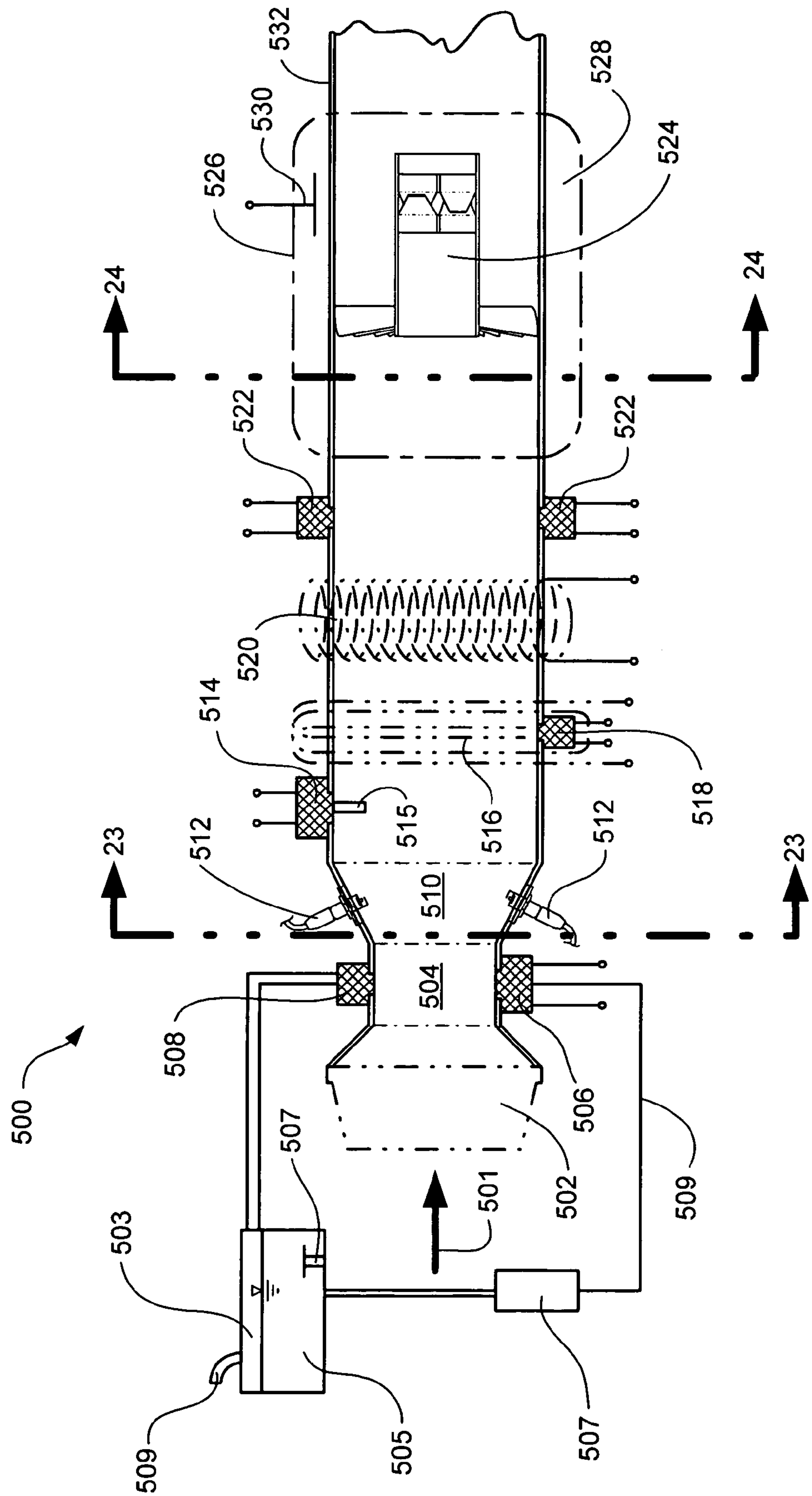

500
501
502
503
504
505
506
507
508
509
510
512
514
515
516
518
520
522
524
526
528
530
532
23
24

FIG. 22

FIG. 23

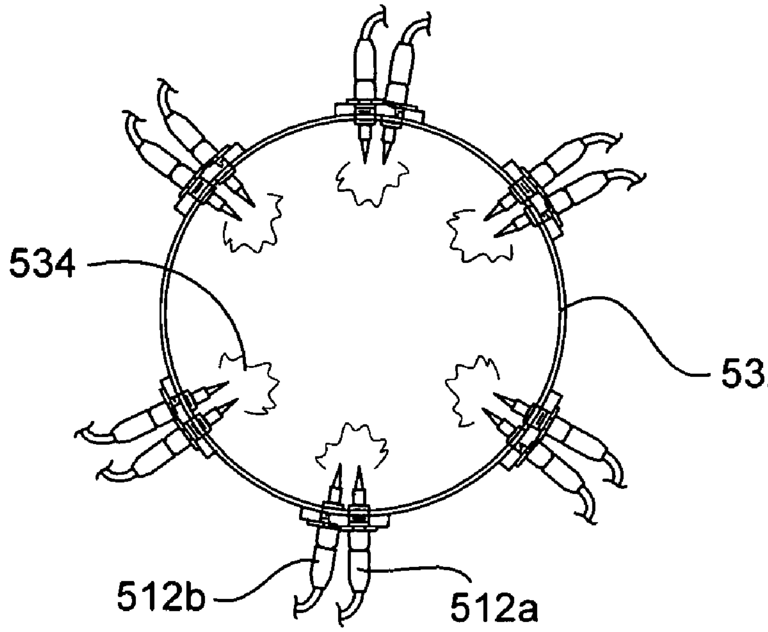
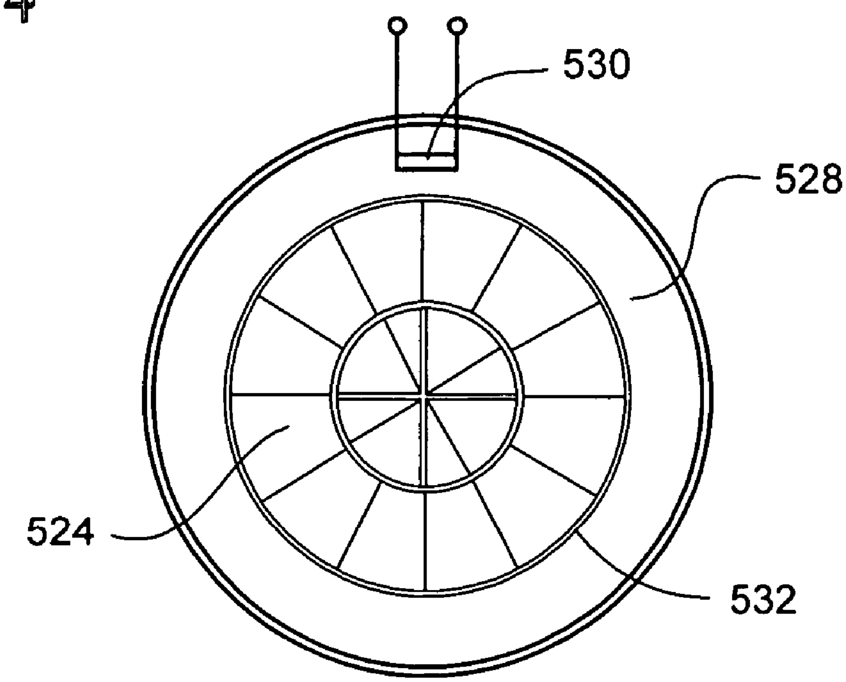


FIG. 24



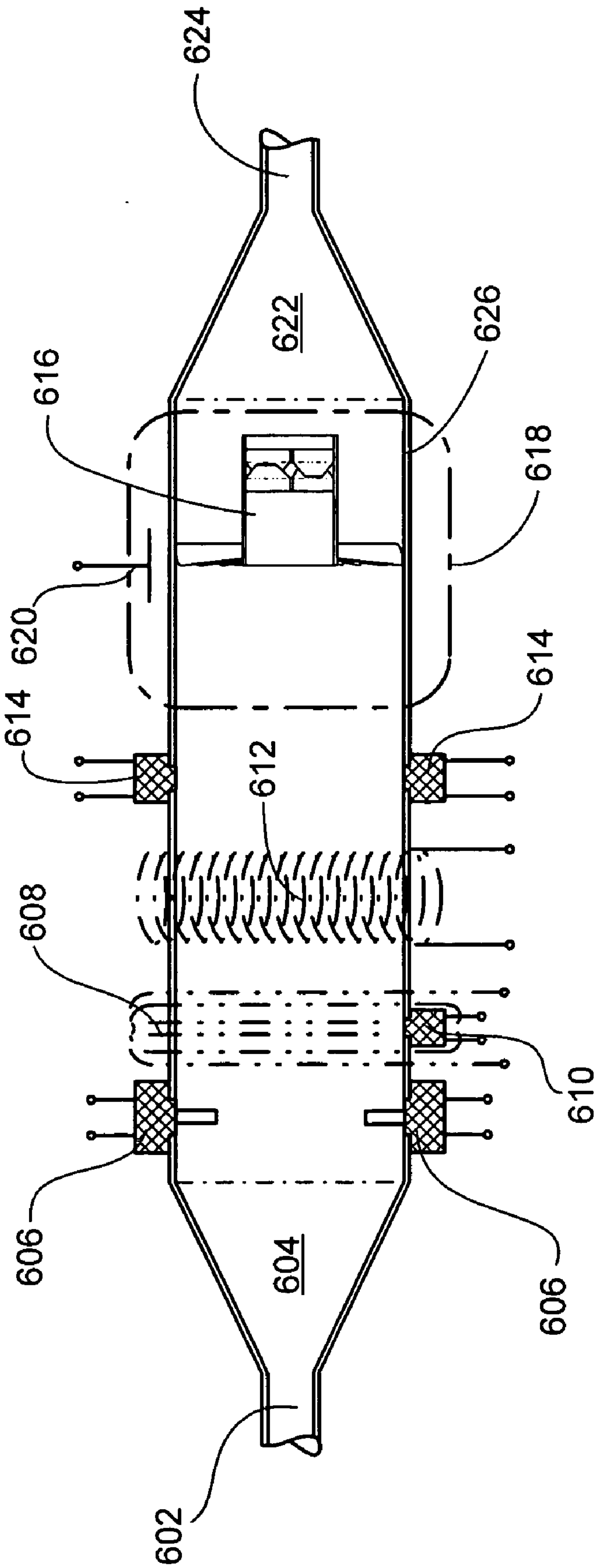


FIG. 25

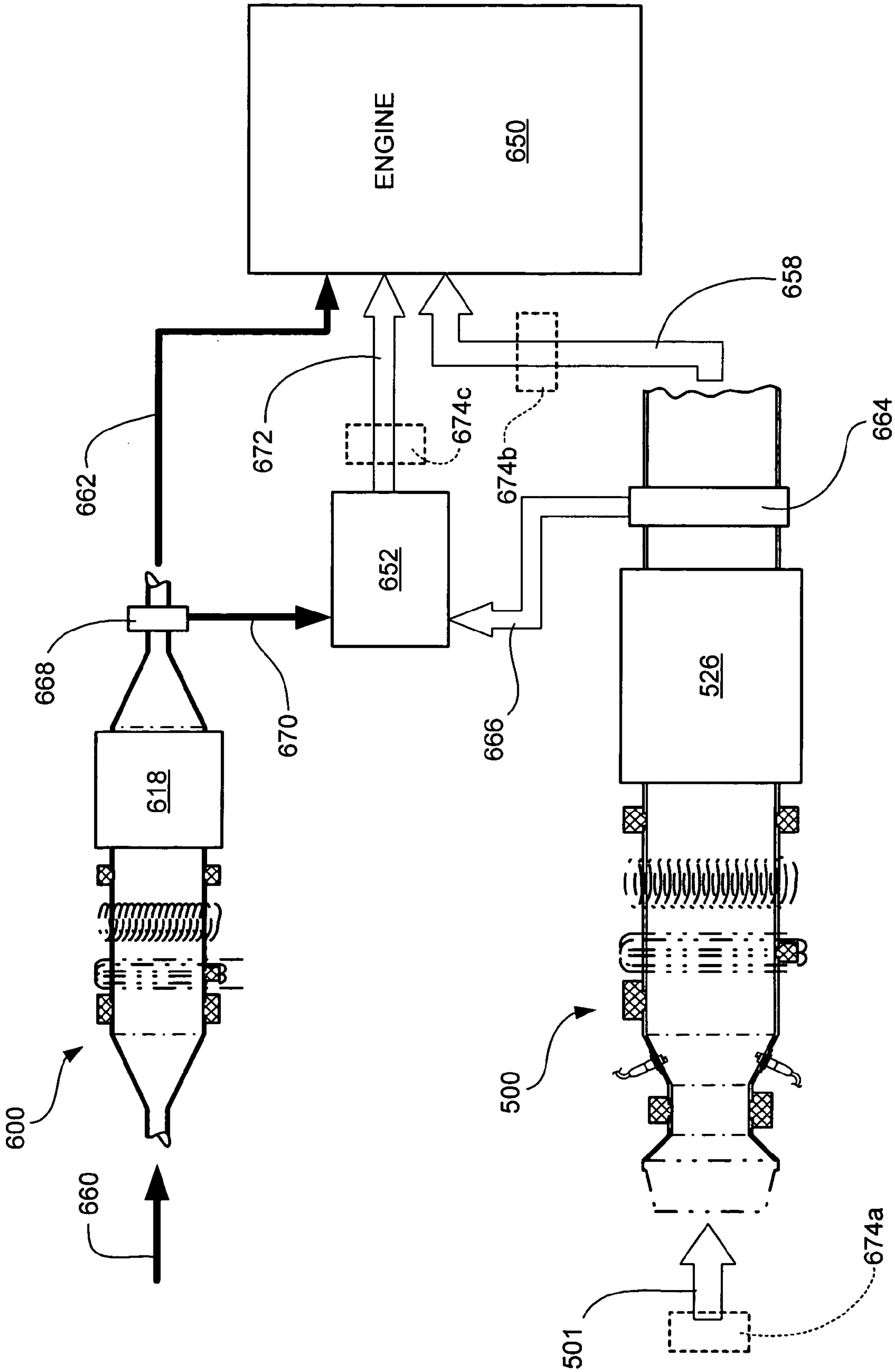

ENGINE
650
658
662
672
674c
674b
664
652
668
670
666
618
526
600
500
660
501
674a

FIG. 26

IONIZING FLUID FLOW ENHANCER FOR COMBUSTION ENGINES

PRIORITY CLAIM

[0001] The present application is a continuation-in-part of U.S. non-provisional patent application No. 11/035,487, filed on Jan. 15, 2005, and entitled GAS FLOW ENHANCER FOR COMBUSTION ENGINES, which claims priority from U.S. provisional patent application Ser. No. 60/580,146, filed Jun. 15, 2004, and entitled PETO TURBORAMJET ENGINE COOLER AND MUFFLER.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates generally to fluid flow in combustion engines. More particularly, the present invention relates to a device for improving the efficiency of fluid flow in an intake or exhaust conduit, or in a fuel conduit, and to the modification of chemical species within engine air intake and liquid fuel, so as to increase engine power and efficiency.

[0004] 2. Related Art

[0005] The principles of operation of combustion engines are well understood. Air and fuel are mixed and drawn into a combustion chamber through inlet valves, where they are ignited. The ignition imparts kinetic energy to mechanical engine components, allowing the engine to do work, and also produces hot waste gasses which are discharged through exhaust valves, and eventually exhausted to the atmosphere.

[0006] In order for the engine to do work, the exhaust pressure must be lower than the combustion pressure. At the same time, it is desirable to dampen the noise from the combustion, and to treat the waste gasses to reduce pollution. Thus, internal combustion engines are typically provided with catalytic converters and particulate traps to reduce emissions of undesirable gasses and particles from inefficient combustion, and mufflers of various kinds to reduce engine noise.

[0007] Unfortunately, these components disposed in the exhaust stream tend to increase exhaust back pressure, thus reducing the power output and efficiency of the engine. This also tends to result in a higher operating temperature for the engine, reducing the life of lubricants and of the engine itself.

[0008] Another challenge with respect to internal combustion engines has been to achieve sufficient mass balance reactivity of the fuel and air to effect complete combustion of the fuel. Incompletely burned fuel exhausted from combustion engines is one major component of modern pollution problems. Additionally, kinetic energy is lost when fuel is unburned or inefficiently burned.

SUMMARY OF THE INVENTION

[0009] It has been recognized that it would be advantageous to develop an intake system for a combustion engine that contributes to more complete and efficient burning of motor fuel.

[0010] It has also been recognized that it would be advantageous to develop a fuel intake system that conditions liquid fuel to promote more complete and efficient burning.

[0011] The invention advantageously provides a ionizing fluid flow enhancer for a fluid conduit of a combustion engine. The ionizing fluid flow enhancer includes a housing having an inlet configured to receive an inlet flow of fluid; at least one fluid modification element, disposed along the housing, configured to chemically alter the flowing fluid; and a spiral vane assembly, configured to produce an outer helical flow of the fluid and an inner helical flow of the fluid within the housing. The spiral vane assembly includes a plurality of outer vanes, disposed around an outer periphery of the housing, configured to produce an outer helical flow of the fluid; a plurality of inner vanes, disposed within a central portion of the housing, configured to produce an inner helical flow of the fluid, the inner helical flow having a higher velocity than the outer helical flow; and a flow separator, disposed between the inner vanes and the outer vanes, configured to separate the fluid flow into outer flow that flows past the outer vanes, and inner flow that flows past the inner vanes.

[0012] Additional features and advantages of the invention will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** is a side, cross-sectional view of one embodiment of a gas flow enhancer, showing the gas flow paths therethrough.

[0014] **FIG. 1B** is a side, cross-sectional view of the gas flow enhancer of **FIG. 1**,

[0015] **FIG. 2A** is a transverse cross-sectional view of the gas flow enhancer of **FIG. 1** showing a first alternative configuration for the outer vanes.

[0016] **FIG. 2B** is a transverse cross-sectional view of the gas flow enhancer of **FIG. 1** showing a second alternative configuration for the outer vanes.

[0017] **FIG. 3** is a partial cut-away perspective view of an alternative embodiment of a gas flow enhancer similar to that of **FIG. 1**.

[0018] **FIG. 4A** is a side, cross-sectional view of the converging section and outlet nozzle of a gas flow enhancer, showing an approximate pressure profile for the exhaust gasses.

[0019] **FIG. 4B** is a side, cross-sectional view of the converging section and outlet nozzle of a gas flow enhancer, showing an approximate velocity profile for the exhaust gasses.

[0020] **FIG. 5** is a perspective view of an engine having an exhaust system with two gas flow enhancers disposed therein, and a gas flow enhancer disposed in the engine air intake.

[0021] **FIG. 6** is a semi-schematic view of an engine turbocharger system including multiple gas flow enhancers in various positions.

[0022] **FIG. 7** is a side cross-sectional view of a dual-stage gas flow enhancer in accordance with the present invention.

[0023] **FIG. 8** is a transverse cross-sectional view of the gas flow enhancer of **FIG. 6**, showing the intermediate flow straightener.

[0024] **FIG. 9** is a side cross-sectional view of an alternative embodiment of a dual-stage gas flow enhancer having a perforated center flow straightener with sound-deadening packing material disposed therearound.

[0025] **FIG. 10** is a perspective view of a set of inner vanes that are suitable for a gas flow enhancer in accordance with the present invention.

[0026] **FIG. 11** is a side, cross-sectional view of an alternative gas flow enhancer configured for injecting gasses into an engine air intake system.

[0027] **FIG. 12** is a side, cross-sectional view of an alternative gas flow enhancer for an exhaust system, having gas injection and charged electrodes disposed near the outlet.

[0028] **FIG. 13** is a side, cross-sectional view of yet another alternative exhaust gas flow enhancer having gas injection and charged electrodes disposed near the inlet.

[0029] **FIG. 14** is a side, cross-sectional view of yet another alternative exhaust gas flow enhancer having gas injection and a spark plug disposed near the inlet.

[0030] **FIG. 15** is a side cross-sectional view of another alternative embodiment of a dual-stage gas flow enhancer having gas injection and charged electrodes disposed in the vicinity of the center flow straightener.

[0031] **FIG. 16** is a side cross-sectional view of yet another alternative embodiment of a dual-stage gas flow enhancer having gas injection and a spark plug disposed in the vicinity of the center flow straightener.

[0032] **FIG. 17** is a schematic view of another embodiment of a gas flow enhancer disposed in an engine air intake system.

[0033] **FIG. 18** is a side, cross-sectional view of the gas flow enhancer of **FIG. 17**.

[0034] **FIG. 19A** is an end cross-sectional end view of one embodiment of a gas flow enhancer having four plasma plugs.

[0035] **FIG. 19B** is an end cross-sectional end view of another embodiment of a gas flow enhancer having eight plasma plugs.

[0036] **FIG. 20** is a close-up view of a spark plug.

[0037] **FIG. 21** is an end cross-sectional view of another embodiment of a gas flow enhancer having plasma plugs with alternating polarity.

[0038] **FIG. 22** is a side cross-sectional view of another embodiment of a gas flow enhancer in accordance with the present invention.

[0039] **FIG. 23** is an end cross-sectional view of an alternative embodiment of a plasma electrode chamber.

[0040] **FIG. 24** is an end cross-sectional view of the gas plasma chamber portion of the fluid flow enhancer of **FIG. 22**.

[0041] **FIG. 25** is a side cross-sectional view of a liquid flow enhancer configured for use in a liquid fuel line.

[0042] **FIG. 26** is a schematic diagram of an engine system provided with a fluid flow enhancer in the air intake and a fluid flow enhancer in the fuel system, and a mixer for preliminarily mixing a portion of the treated air and fuel prior to introduction into the engine.

DETAILED DESCRIPTION

[0043] Reference will now be made to the exemplary embodiments illustrated in the drawings, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Alterations and further modifications of the inventive features illustrated herein, and additional applications of the principles of the invention as illustrated herein, which would occur to one skilled in the relevant art and having possession of this disclosure, are to be considered within the scope of the invention.

[0044] The present invention provides a device for enhancing the flow of gasses in a conduit associated with a combustion engine. As used herein, the term "gas" is intended to have its basic scientific meaning—i.e. a fluid that is not a liquid. The term "fluid", however, is intended to encompass both liquids and gasses. Various embodiments of the present invention are applicable to both exhaust gasses and inlet gasses for an engine, and reduce overall flow pressure, and increase velocity, for greater efficiency. The device includes elements that split the gas stream into two streams, and induce a vortex spin in each stream within a chamber, creating a pressure differential within a laminar flow outlet, decreasing backpressure and encouraging flow.

[0045] One embodiment of a gas flow enhancer **10** in accordance with the present invention is shown in **FIGS. 1A and 1B**. The gas flow enhancer generally comprises a hollow cylindrical housing **12**, with two sets of spiral vanes **14**, **16**. The housing includes an inlet **18**, an outlet **20**, and an expansion chamber **22** between the inlet and outlet. The expansion chamber comprises a generally conical diverging section **24**, a central cylindrical section **26**, and a generally conical converging section **28** interconnecting the central cylindrical section with the outlet. The central cylindrical section has a greater diameter than either the inlet or outlet, with the diverging and converging sections providing a transition between the respective diameters. The diverging and converging sections are designed to provide a gradual transition of flow between the inlet and outlet and the expansion chamber. While the inlet and outlet are shown as having the same diameter, this need not be the case, as discussed below. Additionally, while the inlet and outlet are shown as being circular in cross-section, this need not be the case, either. Other conduit shapes can be associated with the flow enhancer of the present invention.

[0046] The sets of spiral vanes **14**, **16**, are disposed within the central cylindrical section **26** of the expansion chamber **22**. The outer vanes **16** are disposed in an annular space **30** between the wall of the central cylindrical section of the expansion chamber and the outside of an inner cylinder **32**, also called a flow separator or flow splitter pipe. The inner vanes **14** are disposed within the inner cylinder. The inner cylinder separates or splits the gas flow into a central flow portion, denoted by arrow **36**, and an outer or annular flow portion, denoted by arrows **38**. The central flow portion contacts the inner vanes, and the outer flow portion flows past the outer vanes.

[0047] Because of their geometry, the outer vanes **16** produce a spiral or helical flow of gas, essentially a vortex, of the outer flow around the outer periphery of the central expansion chamber **22** of the housing. This outer flow is represented by arrow **38** in **FIG. 1**. The inner vanes **14** produce a spiral or helical vortex within the center of the hollow housing, represented by arrow **36**.

[0048] The configuration of the inner and outer vanes can be varied in many ways. For example, number of outer vanes can vary. The inventors have used twelve outer vanes, but the device can be configured with a greater or lesser number. Likewise, the angle of the outer vanes can vary. One angle that the inventor has successfully used is an angle of about 55 degrees relative to the incoming gas flow, though the relative angle of the outer vanes can vary from this angle. For example, it is believed that angles from about 15 degrees to about 55 degrees can be suitable for a wide range of flow characteristics. The maximum practical angle is desirable in order to maximize the spiral characteristics of the helical flow. However, the creation of turbulence downstream will disturb the flow and drain energy (i.e. velocity), thus reducing the effectiveness of the device. Angles above 55 degrees can be used, but are impractical for many flow conditions. On the other hand, vane angles below about 15 degrees tend to produce a less dramatic spiral flow, providing reduced performance of the gas flow enhancer. Indeed, if the vane angles are too small the helical flow pattern may not be established at all.

[0049] The configuration of the outer vanes can be adjusted in other ways, too. For example, viewing **FIG. 2A**, the outer vanes can have a size and angle such that there is a visible gap between adjacent vanes, allowing a direct line of sight through the outer vanes and to the outlet **20** if one peers through the gas flow enhancer device. Alternatively, as shown in **FIG. 2B**, an alternative configuration of outer vanes **16*b*** can include vanes having a size and/or angle that blocks any direct line-of-sight through the outer vanes and to the outlet. The inventor has found that this latter configuration provides greater muffling of engine noise by blocking more of the direct path for sound.

[0050] The inner vanes **14** can also be configured in various ways. A detail view of one embodiment of the inner vanes is shown in **FIG. 10**. In this embodiment, the inner vanes comprise four flaps **33** bent downwardly from each of an identical pair of cross braces **34**. The rearward of the pair is reversed and placed adjacent the forward one, with a gap between them. The assembly of the two blade sets is attached within the separator pipe **32**, and provides a symmetrical group of eight vanes that together create the tight rotational spin of gases passing through the separator pipe. While this configuration produces eight vanes, it will be apparent that a greater or lesser number of inner vanes can be provided, and these can have different configurations than that shown.

[0051] Because of their closer spacing, the inner vanes **14** produce a tighter central spiral flow with a higher rotational velocity and lower pressure than the outer spiral flow. In the embodiment depicted in the figures, the inner vanes are disposed at an angle of about 55 degrees relative to the incoming gas flow, the angle being selected for generally the same reasons given above with respect to the outer vanes. However, the relative angle of the inner vanes can vary within a range of from about 30 degrees to about 55 degrees. The inventor has found that angles of less than about 30 degrees do not adequately produce the desired central spiral flow.

[0052] There are other notable aspects of the inner and outer vanes. First, while the vanes (both inner and outer) are shown as being generally planar, curved vanes can also be used, with the trailing edges of the vanes having the angles within the ranges mentioned. Additionally, the position of the vanes relative to the inlet and outlet can also be varied. For example, in the configuration of **FIG. 1**, the outer vanes **16** are disposed adjacent to the leading edge **54** of the inner cylinder **32**, while the inner vanes **14** are disposed toward the rear of the inner cylinder, at a distance L_V from the leading edge of the inner cylinder. The outer vanes are configured with a tapered leading edge **58**, and a straight trailing edge. The leading edge is positioned such that the leading edge at the base **57** of each outer vane is set back a distance L_S from the leading edge of the inner cylinder, while the leading edge at the outer end **59** of each outer vane meets the outer cylinder **12** at a positioned substantially aligned with the leading edge of the inner cylinder. The inventor has found that this is an advantageous configuration for the outer vanes.

[0053] Nevertheless, other relative positions for the inner and outer vanes can also be used. For example, in the dual-stage gas flow enhancer embodiment shown in **FIG. 7**, (described in more detail below) the outer vanes **116** are disposed and configured with respect to their supporting inner cylinder like those shown in **FIG. 1**, while the inner vanes **114** are disposed entirely at the rear of the respective inner cylinder. As another alternative, shown in **FIG. 3**, the inner vanes **14*a*** can be disposed near the leading edge of the inner cylinder **32**, while the outer vanes **16*c*** are disposed toward the rear of the inner cylinder. Other variations in position of the inner and outer vanes are also possible.

[0054] As shown in **FIG. 1**, both sets of vanes **14**, **16**, are configured to produce a spiral or helical flow that rotates in a common direction. However, because of differential pressure and velocity characteristics, the lower pressure inner flow **36** remains generally separate from the higher pressure outer flow **38** until reaching the converging section **28**. The expansion chamber contains the rotational gases to reinforce velocity of the gas and affect a vacuum on the upstream side, and propulsion of flow downstream. Within the converging section of the expansion chamber **22** the inner flow and outer flow converge and recombine, then exit through the outlet **20** in a laminar flow condition.

[0055] As the two flows converge, the pressure and velocity characteristics of the inner flow **36** and outer flow **38** persist, producing a laminar outflow with a spatially varying flow profile. That is, as shown by the pressure profile curve **40** of **FIG. 4A**, the flow that is toward the side walls of the outlet conduit, denoted by arrow **42**, has higher pressure than the flow in the center of the outlet, denoted by arrow **44**. Conversely, as shown by the velocity profile curve **46** of

FIG. 4B, the flow that is toward the side walls of the outlet conduit, denoted by arrow **48**, has lower velocity than the flow in the center of the outlet, denoted by arrow **50**.

[0056] Additionally, the overall pressure of the flowing gas at the outlet **20** is lower than at the inlet **18**, such that the average outflow velocity is higher, demonstrating the gas drawing effect the gas flow enhancer device **10** provides. As shown in **FIGS. 1 and 3**, the outlet can also include flow-straightening vanes **52**, which help to redirect the flow and reduce persistence of the helical or spiral flow pattern. While a suitable flow-straightening device can take many different configurations, that shown in the figures comprises flat metal strips or plates disposed at 90 degree angles to each other, and attached inside the respective tube, similar to the cross braces **34** that are part of the inner vanes **14** inside the inner cylinder.

[0057] Various geometric aspects of the flow enhancer **10** contribute to its operation. Viewing **FIG. 1B**, the diameter D_4 of the central cylindrical section **26** of the housing **12** is greater than the size of the inlet or outlet tubes. This allows the spiral vanes and other structure within the expansion chamber to have their effect on the flowing gasses without increasing net back-pressure. In one operative example, the inlet and outlet pipes **18**, **20**, have diameters D_1, D_2 of 2.5 inches, and the central section of the expansion chamber **22** has a diameter D_4 of 3.5 inches. In another operative example, the inlet and outlet pipes have a diameter of 4 inches, and the central expansion chamber has a diameter of 6 inches. These different diameter combinations relate to the size and operating ranges of an engine, and the different flow regimes that will be produced, as described in more detail below.

[0058] As noted above, the inlet and outlet pipes need not be the same size. For example, the inventor has produced an operative system wherein the inlet pipe has a diameter of 4 inches, the central expansion chamber has a diameter of 6 inches, and the outlet has a diameter of 5 inches. The inventor has found that this configuration improves the operation of the flow enhancer. Other size combinations are also possible. Additionally, while it is desirable for the central expansion chamber to be cylindrical, so as to contribute to the spiral flow, the inlet and outlet pipes can be some shape other than circular, such as rectangular, octagonal, etc.

[0059] The inner cylinder **32** has a length L_L, and a diameter D_3 that is smaller than the diameters of the inlet and outlet pipes **18**, **20**. The diameter and length of the inner cylinder are proportional to the overall size of the gas flow enhancer. The inventor has determined workable dimensions for these elements based in part on trial and error. In one operative example, where the diameter D_4 of the central expansion chamber is 3.5 inches, an inner cylinder with a diameter D_3 of 1.6 inches has been found to be suitable.

[0060] The length L_d of the diverging section **24** and length L_c of the converging section **26** depend upon the respective sizes of the inlet and outlet conduits and the central section of the expansion chamber **22**, and the angles of divergence α and convergence β. These angles are selected based largely upon the same considerations discussed above with respect to the angle of the vanes. The divergence and convergence angles can range from about 20 degrees as a practical minimum, to about 55 degrees as a practical maximum. Other angles can also be used. It will be apparent that smaller angles will have the effect of making the gas flow enhancer device longer, which can be undesirable from a space efficiency standpoint.

[0061] The spiral vanes, both the inner vanes **14** and outer vanes **16**, are located toward the inlet **18**, but not immediately adjacent to the inlet. The distance L_1 between the diverging section and the forward edge **54** of the inner cylinder **32** is provided to allow the flow to stabilize after expansion and before splitting. In a 6" diameter flow enhancer, a distance L_1 that has been used is 1.15 inches. In a 10" diameter flow enhancer, a distance L_1 of 1.75 inches has been used. The region between the rearward edge **56** of the inner cylinder and the converging section has a length L_2, and provides an open chamber for the inner and outer vortices (represented by arrows **36**, **38**) to become fully established.

[0062] The distances L_1, L_2 and L_C are functions of the diameter of the central section **26** of the expansion chamber **22** and are selected to provide sufficient distance for full establishment of the helical or spiral flow, both inner and outer. The inner vanes **14** and outer vanes **16**, taken together, are disposed at a location within the expansion chamber that is closer to the inlet than the outlet, the distance from the inlet to the leading edge **54** of the inner cylinder **32** being about one fifth the total distance between the inlet and outlet. In one operative example, where the diameter D_4 of the central section of the expansion chamber is 3.5 inches and the length L_L of the inner cylinder is 2.5 inches, the distances L_1, L_2 and L_C are 0.5 inches, 2.25 inches and 0.5 inches, respectively. The inventor has found that making the outlet end of the expansion chamber longer than what is needed to allow establishment of the helical flow adds little to the performance of the device. For example, the inventor has found that for a device having a 6 inch diameter expansion chamber, the total length of the expansion chamber can be 8 inches to provide adequate operation. Additional length does not appear to improve function significantly.

[0063] Another geometric feature of the gas flow enhancer **10** that contributes to its operation is the setback distance L_S between the front or leading edge **54** of the inner cylinder **32**, and the leading edge **58** of the outer vanes **16** at the base **57** of those vanes. This distance allows the flow to be divided before any disturbance from subsequent elements (e.g. the vanes). In one operative example, where the diameter D_4 of the central section of the expansion chamber is 3.5 inches, the diameter D_3 of the inner cylinder **32** is 1.6 inches, and the length L_L of the inner cylinder is 2.5 inches, a setback distance L_S of about 0.25 inches has been used. In other configurations, where the dimensions of the gas flow enhancer are different, the inventor has used setbacks L_S that are equal to about ten times the length L_L of the inner cylinder.

[0064] The inner vanes **14** are also set back a distance L_V from the leading edge **54** of the flow splitter pipe **32**. The inventor has determined the desirability of this distance through experimenting with a variety of configurations. It is believed that this distance reduces turbulence in the inner annular flow, and therefore contributes to efficient establishment of the inner helical flow. In the embodiment of **FIG. 1**, for example, the distance L_V is significantly greater than the setback L_S of the outer vanes, but not so great as to place the vanes at the rear extremity of the inner cylinder. In the embodiment of **FIG. 7**, a setback L_V which places the inner vanes at the rear extremity of the flow splitter pipe has been used effectively. However, other configurations have also been used. For example, the configuration shown in **FIG. 3** places the inner vanes near the leading edge of the inner cylinder, with a small setback (approximately equal to the value of L_S discussed above) and the outer vanes disposed rearwardly a distance.

[**0065**] As noted above, different relative diameters of the expansion chamber and inlet and outlet conduits relate to the size and operating ranges of an engine, and the different flow regimes that will be produced. That is, a smaller diameter gas flow enhancer operates effectively for lower flow rates than a larger one, and therefore is to greatest advantage for a smaller engine and/or an engine operating at a lower speed (e.g. lower RPM). Alternatively, a larger flow enhancer is needed for a larger engine and an engine operating at higher RPMs. The different diameters and range of acceptable diameters for a given engine also allow one to "tune" the exhaust system, and thus reduce noise and the incidence of backfiring.

[**0066**] Additional embodiments of the gas flow enhancer for use in an exhaust stream are shown in **FIGS. 12-14**. These embodiments provide systems wherein hydrogen gas or other reactant gas can be injected into the exhaust stream and ignited and/or ionized to produce what can be called an exhaust gas transforming plasma (EGTP) muffler. These embodiments operate on some of the same principles outlined in U.S. Pat. No. 5,603,893 to Gunderson, et al. In the views of **FIGS. 12-14**, the gas flow enhancer units **10** are shown in the same general orientation as in **FIG. 1**, with exhaust gas flow (indicated by arrows **90**) moving from left to right. In these views, the flow-straightening vanes (**52** in **FIG. 1**) are not shown, but it is to be understood that the structures described above for creating the desired flow are presumed to be included.

[**0067**] In the embodiment of **FIG. 12**, the gas flow enhancer **10***b* includes an injection tube **92** and nozzle **94** for introducing gaseous hydrogen or other reactant gas into the exhaust stream near the inlet of the gas flow enhancer device. The hydrogen or other gas can be produced by various types of gas generators (not shown) that are commercially available. For example, hydrogen can be produced using an electrolysis unit (not shown) that produces gaseous hydrogen from water. A pump (not shown) can be provided to pump the reactant gas from the electrolysis unit through the injection tube and nozzle.

[**0068**] The gas mixes with the flowing exhaust gases as it passes through the helical vanes and other structure in the gas flow enhancer unit **10***b*, in the manner described above. As it flows, some of the hydrogen may react with various waste gasses, including pollutants, in the exhaust stream. This has the beneficial effect of reducing undesirable emissions from the engine. When the exhaust gas reaches the end of the gas flow enhancer unit, it is highly ionized and passes an electrode device, such as an anode/cathode pair **96**, **98**, which provide an electrical charge. This electrical charge causes the hydrogen remaining in the exhaust stream to combust and/or ionize, along with any other unburned species that may remain in the exhaust stream. This creates a plasma cloud **100** near the outlet end of the gas flow enhancer unit. This plasma cloud improves emissions by reforming the gas and/or consuming unburned fuel species, and also creates a low pressure condition that helps improve flow through the gas flow enhancer unit.

[**0069**] In an alternative embodiment of the EGTP muffler concept, shown in **FIG. 13**, the gas flow enhancer unit **10***c* includes an injection tube **92** and nozzle **94** for introducing gaseous hydrogen near the inlet of the gas flow enhancer device, similar to the placement in the embodiment of **FIG. 12**. However, in this embodiment the electrode device, the anode **96** and cathode **98**, is also disposed near the inlet of the device, producing the plasma cloud **100** at the inlet. This embodiment works well in a turbo down pipe, as described in more detail below, where its effect is to spool up the turbo faster, so as to produce turbo boost at lower RPM levels. This is believed to increase performance and fuel efficiency, and decrease emissions. In this embodiment, the pressure and flow characteristics of the exhaust flow are improved (i.e. vacuum is created) at the inlet of the device, rather than near the outlet. The effect is to improve the pressure differential across the device, and increase the flow rate of gas through the device. Additionally, while the hydrogen will not have an opportunity to substantially mix with the exhaust gases before combustion, the combustion in a low pressure environment will still help consume unburned hydrocarbons and other pollutants that otherwise would be exhausted to the atmosphere.

[**0070**] Yet another alternative embodiment of a gas injection EGTP device **10***d* is shown in **FIG. 14**. This embodiment is like that of **FIG. 13**, except that the electrode device comprises a spark plug **102**, instead of an anode/cathode pair. Like the anode cathode pair, the spark plug, firing at a frequency of about 15 kHz, has the effect of producing ionization/combustion of the gases near the inlet of the gas flow enhancer device. This embodiment also has the advantage that it uses common off-the-shelf parts (a conventional spark plug), rather than unusual or specialty parts.

[**0071**] It is to be understood that the elements of the various embodiments shown in **FIGS. 12-14** can be put together in a variety of additional combinations that are not shown. For example, in the embodiment of **FIG. 12 a** spark plug, such as that shown in **FIG. 14**, can be provided at the outlet end of the device in place of the anode and cathode **96**, **98**. Other combinations are also possible.

[**0072**] Multiple gas flow enhancers of different dimensions can be provided in a single exhaust system to provide their effects at different operating speeds. For example, shown in **FIG. 5** is a four cylinder internal combustion engine **60** with an exhaust manifold **62** that converges into an exhaust pipe **64**, leading to a catalytic converter **66**. Following the catalytic converter, two gas flow enhancers **10***a*, **10***b*, configured as discussed above, are disposed in the exhaust pipe. The first gas flow enhancer **10***a* has a smaller diameter and is most effective at lower speeds, while the second larger diameter gas flow enhancer **10***b* is primarily effective at higher speeds.

[**0073**] In one operative example, the inventor tested a 1996 Mitsubishi 3000GT with a gasoline-powered turbocharged 3.0 liter V6 engine both before and after the installation of a dual in-line gas flow enhancer system in the vehicle exhaust system. This system included two gas flow enhancer devices installed in series on each side of the dual exhaust system of the vehicle. The gas flow enhancer disposed nearer the engine was a 3.5 inch diameter unit, and that toward the discharge end of the exhaust system was a 6.0 inch diameter unit. Before the installation, with a stock exhaust system, the dynamometer test showed the vehicle to have a peak power of 188.5 Hp at 4900 rpm, and peak torque of 223.3 ft-lb at 3700 rpm. After installation of the gas flow enhancer system, the same vehicle showed peak power of 255.2 Hp at 5100 rpm, and peak torque of 287.0 ft-lb at 3500 rpm.

[0074] In another operative example, the inventor tested a 2000 Ford F-250 pickup truck with a fuel-injected 7.3 liter V8 Deisel engine both before and after the installation of a single 6.0 inch diameter gas flow enhancer device at the discharge end of the vehicle exhaust system. Before the installation, with a stock exhaust system, the dynamometer test showed the vehicle to have a peak power of 258.9 Hp at 3000 rpm, and peak torque of 516.8 ft-lb at 2500 rpm. After installation of the gas flow enhancer device, the same vehicle showed peak power of 268.1 Hp at 2750 rpm, and peak torque of 522.3 ft-lb at 2500 rpm.

[0075] In yet another operative example, the inventor has installed a gas flow enhancer on a class 8 Volvo semi tractor having a Cummins ISX Deisel engine rated at 475 Hp. Prior to the installation, the truck had an average fuel economy of 6.47 mpg. After the installation, the same truck's average fuel economy over the ensuing fourteen months increased to 7.79 mpg, an increase of about 20%.

[0076] The various embodiments of the gas flow enhancer device shown in **FIGS. 1-5** and **12-14** all provide a single set of inner and outer vanes and a single expansion chamber. Shown in **FIG. 7** is an alternative embodiment of a gas flow enhancer **110** having a dual-chamber or dual-stage configuration. Like the above-described embodiments, this embodiment comprises a housing **112** with an inlet **118** for receiving flowing gas, and an outlet **120** for discharging the gas. The housing includes a diverging section **124**, disposed adjacent the inlet, and a converging section **128** disposed adjacent the outlet.

[0077] Unlike the above-described arrangements, the flow enhancer **110** of **FIG. 7** includes more than one set of vanes and splitter pipes for producing the helical or spiral flow. The device includes a first expansion chamber **122***a*, within which are a first set of inner vanes **114***a* and first set of outer vanes **116***a*, attached to a first inner cylinder **132***a*. The first set of vanes operate in the manner described above, producing inner and outer vortices which improve the flow of gas through the device. The first sets of vanes are followed by an intermediate converging section **134**, which includes a flow straightener **136**, like those described above. A cross-sectional view showing the intermediate converging section and flow straightener is provided in **FIG. 8**.

[0078] Beyond the outlet of the intermediate converging section **134**, the housing opens again to a second expansion chamber **122***b*, in which is a second set of vanes, including a second set of inner vanes **114***b* and second set of outer vanes **116***b*, attached to a second inner cylinder **132***b*. The second set of vanes operate in the same manner as the first, though the flow parameters will be slightly different at the inlet of the second set than at the inlet of the first. The first and second sets of vanes are configured substantially the same, and their relative configurations can be varied in any of the ways discussed above. The configuration of **FIG. 7** essentially represents two flow enhancers disposed in series, but contained within a single housing.

[0079] An alternative embodiment of a dual-stage gas flow enhancer device **210** similar to that of **FIG. 7** is depicted in **FIG. 9**. In this embodiment, the intermediate converging section **234** and flow straightener **236** are followed by an intermediate diverging section **238** that allows the flow to gradually expand into the second expansion chamber **222***b*. This helps reduce turbulence in the flow as it expands a second time, and thus improves flow. The annular space **240** between the intermediate flow straightener and the outer wall of the housing **212** can be filled with packing material **242**, such as is commonly used in automobile mufflers. The central flow straightener tube **244** can include a plurality of small openings **246** around its sides that allow communication between the annular chamber of packing material and the flow of gas. Because the annular chamber has no outlet, there will be no actual or net flow of gas thereinto. However, the openings allow some of the noise associated with the flowing gas to be dampened by the packing material, perhaps by as much as 10 dB.

[0080] Other alternative dual-stage gas flow enhancer configurations are shown in **FIGS. 15 and 16**. In these embodiments, the inlet **218** includes a gas injection tube **292** and nozzle **294** for injection of a reactant gas, as discussed above. Then, an electrode device is disposed within the central flow-straightener **236**. In the embodiment of **FIG. 15**, the electrode device comprises an anode **296** and cathode **298**, which are electrically charged and have the effect of producing a plasma cloud **300** near the inlet region of the second expansion chamber. In the embodiment of **FIG. 16**, the electrode device comprises a spark plug **302** disposed in the central flow straightener **236**. These configurations provide the advantages discussed above with respect to gas injection and ignition/ionization of the mixed gas stream, but do it in the dual-stage gas flow enhancer unit.

[0081] A gas flow enhancer according to the present invention can also be used in gas flow conduits other than exhaust conduits. For example, as shown in **FIG. 5**, an inlet gas flow enhancer **80** can be disposed in an engine air intake **82**. In such an installation, the inlet **84** to the gas flow enhancer is open to the atmosphere, and the outlet **86** is attached to the engine intake. Because the device reduces pressure at its outlet, it provides more efficient flow of gas (i.e. air) into the engine **60**, and hence reduces the vacuum pressure needed for intake air. It also provides a smooth, efficient laminar flow of air with lower pressure and higher velocity at the center of the flow, which also reduces the temperature of intake air.

[0082] One or more gas flow enhancers as described herein can also be used in connection with a turbocharger, to increase turbocharger boost, and to allow higher boost without actuating the turbocharger wastegate. Such a configuration is shown in **FIG. 6**. As is well known, the turbocharger **310** uses the flow of exhaust gasses from the engine **312** to spin a turbine **314**, which in turn powers an air pump or compressor **316**. The air pump is typically located between the engine air intake **318** and the intake manifold **320** of the engine, and pressurizes the air going into the cylinders. This increases the quantity of air available for combustion, which increases the power output of the engine.

To further improve boost, a turbocharger system may include an intercooler **322**, which cools the intake air after compression by the air pump and before introduction into the engine. This increases engine power because cooler air is more dense.

[**0083**] The turbocharger **310** is attached to the exhaust manifold **324** of the engine **312**. The exhaust from the cylinders passes through the turbine **314**, causing the turbine to spin. After passing through the turbine blades, the exhaust gasses are expelled through the turbo down pipe **326**, which leads to the engine exhaust system (not shown). The turbocharger may also include a wastegate (not shown), which is an internal valve that allows the exhaust to bypass the turbine and directly enter the engine exhaust system if boost pressure gets too high.

[**0084**] The gas flow enhancer of the present invention can be used in many ways in connection with a turbocharger to improve performance. As discussed above, one or more gas flow enhancers can be associated with the engine exhaust system (downstream of the turbo down pipe **326**). These will help improve the flow of exhaust gasses through the turbine portion of the turbocharger. Additionally, a gas flow enhancer **328** disposed in the air intake **318** will help improve the flow of air into the compressor portion **316** of the turbocharger **310**.

[**0085**] Additionally, one or more gas flow enhancers **330** can be provided in the air line **332** before and/or after the intercooler **322**. While the intercooler improves turbo boost by cooling the intake air, some of its benefit is reduced by the mere fact that the intercooler itself interposes an obstruction in the air flow passageway. The provision of one or more gas flow enhancers before and/or after the intercooler help to compensate for the flow hindrance and pressure drop that the intercooler introduces. This helps improve the efficiency of the intercooler.

[**0086**] It is also believed that a gas flow enhancer (not shown) according to this invention could be disposed between the exhaust manifold **324** and the inlet of the gas turbine **314** to improve the flow of gasses into the turbocharger. However, it is expected that such a configuration, while possible, is likely to be impractical in many situations. Nevertheless, the provision of any or all of the gas flow enhancers shown in **FIG. 6** can help to reduce back pressure and increase turbocharger performance. These devices provide a negative pressure that allows more rapid spool-up of the turbocharger **310** at lower RPM, thus reducing turbocharger lag and increasing engine performance and efficiency.

[**0087**] An additional alternative feature of the turbocharger related systems is also shown in **FIGS. 6 and 11**. The inventor has found that injection or production of certain reactant gases in the engine intake can improve performance. Such gases include ozone and hydrogen. As shown in **FIG. 6**, the intake system can include a gas generator **332**, for generating the reactant gas, and an injector tube **334** for introducing the gas into the gas flow enhancer **330** that is just downstream of the intercooler **322**. In the view of **FIG. 11**, this gas flow enhancer unit is shown in the opposite orientation as shown in **FIG. 9**, with air flow (indicated by arrow **336**) moving from left to right.

[**0088**] The gas generator **332** can include a pump for pumping the gas through the injector tube **334**, for injection through an injector nozzle **338** into the intake end of the gas flow enhancer unit. The gas generator can take many forms. In one embodiment, the gas generator can be an ozone generator that uses a high voltage, low current Tesla coil to produce ozone using an electric arc. Ozone generation devices are well known and are widely available. The mixture of ozone into the intake air increases the oxygen content of the air, and thus improves combustion. Alternatively, the gas generator can be a hydrogen generator, such as an electrolysis unit that produces gaseous hydrogen from water, as described above. The injection of hydrogen into the intake air can boost combustion by providing additional fuel. Additionally, the boost it provides will not produce more pollution, given that the only chemical product of hydrogen combustion is water.

[**0089**] In one operative example, the inventor has installed a hydrogen injection system in a gas flow enhancer unit just downstream of the intercooler in a Volvo Detroit Series 500 Hp Deisel engine. This vehicle went from an average fuel economy of 6.4 mpg before the installation, to an average of 8.8 mpg after.

[**0090**] Other alternative configurations for the gas flow enhancer **330** of **FIG. 11** can also be provided. For example, instead of the gas injection tube **334**, the inlet region of the device can be provided with an anode/cathode pair (like the anode **96** and cathode **98** in **FIG. 13**) or a spark plug (like the spark plug **102** in **FIG. 14**) which create an electric arc to produce ozone directly in the inlet gas stream itself, rather than having the ozone produced elsewhere and pumped in. This configuration provides the advantages of introducing ozone into the system, but is simpler in configuration.

[**0091**] While the advantages to gas flow have been mentioned above, the gas flow enhancer also provides other benefits. First, in an exhaust system it reduces noise, like a muffler, but without using baffles, packing, and other back pressure-inducing structure common to conventional mufflers. The inventor has found that a vehicle provided with a gas flow enhancer as described above has no need for a conventional muffler in order to comply with generally accepted vehicle noise standards. The noise reduction is believed to be caused in part by the interruption in flow that the device provides. Specifically, noise from an internal combustion engine is produced by sharp flow pulses from the explosions in each cylinder. However, by producing the separated vortices, the gas flow enhancer disrupts the pulsatile flow, and thus disrupts the noise that the pulses would transmit. The device has been found to effectively lower the frequency of engine noise, and thus effectively reduce the amount of audible engine noise. Additionally, where overlapping outer vanes are provided, as depicted in **FIG. 2B**, the noise reduction is even greater.

[**0092**] The inventor has also found that the gas flow enhancer reduces engine operating temperature. This is believed to be the result of reducing exhaust back pressure, which causes the combustion to be more complete, thus producing less thermal energy and more kinetic energy. This reduced operating temperature naturally increases the life and effectiveness of lubricants and engine components, resulting in longer life of the engine.

[**0093**] The invention as disclosed herein thus provides an engine breathing and cooling apparatus that reduces outflow pressure of gasses in a conduit. It can be used to encourage exhaust flow away from an engine, or to encourage inflow of intake air into an engine, or in other areas where gas flow is present. It is believed that the device can be used with any internal combustion engine, and promotes more complete combustion, increases the efficiency and horsepower of the engine, lowers exhaust gas temperature, increases fuel economy, reduces emissions, increases lubricant and engine life, lowers soot output, and encourages the removal of carbon deposits from the engine. The device also functions as a muffler by naturally lowering the frequency of exhaust noise, thus effectively reducing the level of audible engine noise.

[0094] As noted above, another challenge with respect to internal combustion engines has been to achieve sufficient mass balance reactivity of the fuel and air to effect complete combustion of the fuel. Incompletely-burned fuel exhausted from combustion engines is one major component of modern pollution problems. Additionally, kinetic energy is lost when fuel is unburned or inefficiently burned. As shown and described with respect to **FIGS. 5 and 6**, a gas flow enhancer configured to provide the benefits of helical gas flow can be used in the air intake of an engine, both for air intake from the atmosphere, and for air intake from a turbocharger system.

[0095] Advantageously, the inventors have devised a system by which the combustion constituents for an internal combustion engine can be modified and optimized, thereby increasing efficiency and power, while reducing pollutant emissions and operating temperature of the engine. Shown in **FIG. 17** is a schematic view of an engine system **400** having a gas flow enhancer and ionizer disposed in the combustion air intake from atmosphere, and in the turbocharger downpipe. This configuration is similar to that shown in **FIG. 6**, except that the gas flow enhancers include a plurality of electrodes that produce an ionizing discharge that modifies the chemical composition of the intake air. As with the embodiment of **FIG. 6**, this embodiment includes a turbocharger **410** attached to the exhaust manifold **424** of the engine **412**. The exhaust gasses spin a turbine **414**, which powers the compressor **416**, located between the engine air intake **418** and the intake manifold **420** of the engine. The intercooler **422** cools the intake air after compression by the air pump and before introduction into the engine. After passing through the turbine blades, the exhaust gasses are expelled through the turbo down pipe **426**. In the embodiment of **FIG. 17**, an ionizing gas flow enhancer **428** is disposed in the air intake **418**, and also in the air line between the intercooler **422** and the intake manifold **420**. It will be apparent that the ionizing gas flow enchancers associated with a given engine system may have different dimensions, depending upon their location and the flow they are intended to accommodate.

[0096] Unlike the gas flow enhancers depicted in **FIG. 6**, however, the ionizing gas flow enhancers **428** in the system of **FIG. 17** include a plurality of electrodes **450** disposed near their intake, which create a corona or plasma discharge or cloud that initiates chemical reactions in the intake air. Provided in **FIG. 18** is a side, cross-sectional view of an ionizing gas flow enhancer **428** as used in **FIG. 17**. Provided in **FIGS. 19A, 19B**, and **21** are cross-sectional end views of different embodiments of the same. As can be seen from these figures, the gas flow enhancer includes an inlet **440**, an outlet **442**, and inner and outer helical vanes **444**, **446**, for producing the helical flow and other features described above with respect to other embodiments. Additionally, this embodiment also includes a plasma chamber region **448**, adjacent to the inlet, in which a plurality of electrodes **450** are located.

[0097] The number of electrodes **450** can vary. In one embodiment, shown in **FIG. 19A**, four electrodes are generally symmetrically disposed around the perimeter of the plasma chamber **448**. Alternatively, in the embodiment shown in **FIG. 19B**, eight electrodes are disposed around the perimeter of the plasma chamber. Similarly, eight electrodes **452*a***, **452*b*** are also provided in the configuration of **FIG. 21**. It will be apparent that other quantities and arrangements of the electrodes can also be used, and the ionizing gas flow enhancer is not limited to any particular number.

[0098] As with the number of electrodes, the configuration of the electrodes can also vary. As shown in **FIGS. 18-19**, the electrodes **450** can be motor vehicle spark plugs. These can be specially adapted spark plugs, or they can be essentially off-the-shelf items. This aspect of the ionizing gas flow enhancer makes it economical to manufacture. A closer view of a spark plug **450** is shown in **FIG. 20**. As is well known, ordinary spark plugs include an anode and cathode pair within each plug. The anode **454** and cathode **456** are separated by a gap **458**, and the spark fires across the gap. Alternatively, a different type of electrode can also be used, as shown in **FIG. 21**. This electrode, indicated generally at **452**, includes a single pole **460**, rather than an anode cathode pair, and thus requires that separate anode and cathode units be provided. As shown in **FIG. 21**, the anode and cathode units are alternately positioned around the plasma chamber. Every other electrode **452*a*** is a positive pole, and is connected to the high voltage source. The other electrodes **452*b*** provide a negative pole, and are connected to ground. The result of this configuration is that a plasma cloud **462** is created between each anode-cathode pair, thus producing a larger plasma cloud that affects a larger proportion of the air that passes through the gas flow enhancer. The high voltage source can be an electronic controlled automotive coil, a transformer, a magneto, a neon transformer, or Tesla coil. The electrodes can be driven by a timer circuit configured to provide pulsatile direct current. It will be apparent that the required voltage will vary depending upon the gap between respective anode/cathode pairs. One voltage range that can be used is from 15,000 to 555,000 volts, and at a frequency in the range of from 15 Hz to 15 KHz.

[0099] The exposure of the flowing gas to the plasma cloud causes ionization and ozonation of the intake air. Whether the electrodes are configured as spark plugs, as single pole electrodes, or in come other configuration, the ionizing corona or plasma cloud is believed to split ordinary diatomic oxygen (O_2) in the intake air, leaving two active oxygen ions. These charged particles then quickly react with other species in the intake air. There are at least two basic reactions that occur. First, free oxygen ions attach to diatomic oxygen molecules to form ozone (O_3). Other oxygen ions react with diatomic nitrogen (N_2) to form nitrous oxide (N_2O). Additionally, disturbance to the air via the helical vanes also results in the ionization of the air. The presence of ozone and nitrous oxide in the combustion air, along with a proportion of ordinary oxygen (O_2) that also remains, encourage more complete combustion, thereby producing more power while simultaneously reducing emissions and operating temperatures. Lower emissions reduce fouling of spark plugs and other carbon deposits in the engine, and also reduces unburned fuel that blows by the pistons, thus contributing to longer life of engine lubricating oil. Other chemical species, such as pure oxygen and hydrogen, can also be introduced into and mixed with the modified gas flow, after its contact with the plasma field.

[0100] Another embodiment of a fluid flow enhancer and ionizer **500** in accordance with the present invention is shown in a side cross-sectional view in **FIG. 22**. This fluid flow enhancer includes a series of fluid modification elements that chemically alter the flowing fluid, in addition to the helical vanes and other structure that create the spiral flow. As used herein, the term "chemically alter" is intended to include the creation or introduction of different chemical species (e.g. hydrogen, oxygen, ozone, nitrous oxide, water, etc.), ionization of any species that are present, and the initiation of a phase change (e.g. changing between solid, liquid, gas, or plasma) in the flowing fluid. The embodiment of **FIG. 22** is configured for engine intake air, though its overall configuration and many of its elements can be used with other fluids, including liquids such as motor fuel, as will be discussed with respect to **FIG. 25**.

[0101] Intake air, represented by arrow **501**, enters the fluid flow enhancer through an air filter **502**, and then passes into a first restricted conduit region **504**. Disposed within the first restricted conduit region is a water injector **508**. This injector draws water vapor from the head space **503** of a water reservoir **505**, and injects the water vapor into the first restricted conduit region. Injection of the water vapor is naturally promoted by relative vacuum pressure which will naturally exist in the restricted region **504** due to the higher velocity gas flow therein, and injection can also be promoted with pumps if desired. The water reservoir also includes a vent **509** to atmosphere.

[0102] To promote vaporization of the water, the water reservoir **505** can also include an ultrasonic device **507**, which mechanically vibrates within the water at an ultrasonic frequency. Ultrasonic vibration of water is known to promote vaporization, and this approach is currently used in a wide variety of devices, including ventilation systems and room air fresheners. The injection of water vapor has several beneficial effects in the ionizing fluid flow enhancer. First, it provides an additional source of hydrogen and oxygen. Additionally, the water vapor increases the density of the intake air, which is known to aid combustion, and also lowers the temperature of the exhaust gases after combustion.

[0103] The water reservoir **505** can also be controlled for pH. For example, a chemical injection system **507** can be provided to inject sodium- or potassium-hydroxide (NaOH or KOH) or other chemical species into the water reservoir to change the pH of the water. Controlling the pH of the water can help increase the electrical conductivity of the water vapor, which aids in the production of ozone and other species therefrom, and can also change the surface tension of the water, which can improve vaporization. The ionizing fluid flow enhancer system can also include a sensor **506** in the first restricted conduit region **504** to sense such factors as the relative humidity of the air (after injection of the water vapor), and the pH of the water vapor. The humidity and pH signals can be provided as feedback via electrical communication line **509** to the water supply and chemical injection system **505**, **507** for controlling the rate of water injection and pH modification.

[0104] A plasma chamber is provided within the diverging section **510** of the gas flow enhancer. The plasma chamber includes a plurality of electrodes **512** that produce an electric arc plasma, thereby charging or ionizing the intake air. The high voltage supply can be from an automotive coil, transformers, neon transformer, magneto, or Tesla coil. As shown in **FIG. 22**, the electrodes can be spark plugs. However, other configurations can also be used, and the number of electrodes can vary. For example, the plasma chamber in the embodiment of **FIG. 22** can be configured like any of the embodiments shown in **FIGS. 13, 14, 18, 19***a-b* or **21**, having any number of electrodes, and with the electrodes comprising individual anode/cathode devices (e.g. spark plugs) or proximal anode/cathode pairs. For example, the plasma chamber can include multiple electrodes arranged in a circle and having alternating polarity to provide anode/cathode pairs like the configuration of **FIG. 21**.

[0105] As another alternative, a plurality of single electrodes **512** mounted in proximal pairs can be provided, as shown in the end cross-sectional view of **FIG. 23**. In this configuration, the plasma electrodes each comprise a pair including an anode **512***a* and a cathode **512***b*. These electrode pairs are attached through the outer shell **532** of the gas flow enhancer unit, having their electrode points in sufficient proximity to produce an electric arc **534** therebetween.

[0106] Referring back to **FIG. 22**, after leaving the diverging section **510**, the air flow enters the generally constant diameter main portion of the fluid flow enhancer conduit. At the beginning of this portion of the unit the air first encounters a transducer **514** that generates ozone from the fluid flow. This transducer can include a piezo-electric element **515** that protrudes into the fluid flow and vibrates at an ultrasonic frequency. The physical contact of the vibrating transducer element with the fluid flow produces ozone. It will be apparent that multiple such transducers can be provided in the ionizing fluid flow enhancer unit.

[0107] Further along the length of the fluid flow enhancer conduit is a helical electrical coil **516** that is wound around the outside of the gas flow enhancer conduit **532**. This coil creates a magnetic field that ionizes the air within the gas flow enhancer chamber. A resistive element **518** is provided in the coil windings. In one embodiment, the resistive element is an LED. This configuration both provides the desired resistance, and also can provide a visual indication of the operation of the coil.

[0108] Also wrapped around the outside of the gas flow enhancer conduit **532** is a torroid coil **520** that also produces a magnetic field to ionize the fluid within. The torroid coil produces a magnetic field of a different shape and having a different magnetic flux density variation from that produced by the helical coil **516**. The different shape and density of the magnetic fields produced by the coils **516** and **520** can affect the flowing air in different ways. It is believed that in some applications one or the other of the helical and torroid coils will be more effective, and that in some situations both may be desirable.

[0109] Disposed further along the length of the fluid flow enhancer conduit **532** is a photonic device **522** that exposes the flowing fluid to light energy. The photonic device can be a laser or a UV lamp, for example, and produces ozone in the flowing gas via photonic interaction, in a manner that is well known.

[0110] Disposed around the outer shell **532** of the gas flow enhancer in the region of the inner and outer helical vane assembly **524** is a high voltage gas plasma chamber **526**. Again, as noted above, the high voltage supply can be from an automotive coil, transformers, neon transformer, magneto, or Tesla coil. An end cross-sectional view of the gas plasma chamber region of the gas flow enhancer is shown in **FIG. 24**. The gas plasma chamber includes an outer shell that is enclosed on each end so as to create an enclosed annular chamber **528** against the outside of the shell **532** of the gas flow enhancer. The annular chamber is filled with a noble gas and operates on a principle similar to that of neon lights. Disposed within the annular chamber is a charging device **530** that provides an electrical charge to the gas. The charged gas envelopes the gas flow enhancer shell, and thus spreads or distributes the charge along the entire length of the gas plasma chamber shell. This charges the fluid flow enhancer conduit **532** in that region, and thus also charges the gas flowing therein. One material that the inventor has found useful for the outer conduit is a nickel copper alloy (NiCu).

[0111] The water injector **508**, plasma electrodes **512**, ultrasonic transducer **514**, helical coil **516**, torroid coil **520**, photonic device **522**, and gas plasma chamber **526** are collectively referred to as "fluid modification elements". These fluid modification elements can be provided (or eliminated) in a variety of combinations, and can be provided in an order different than that shown. Many of these elements produce similar results, e.g. the production of free hydrogen, ozone, nitrous oxide, etc. in the fluid stream, but do so by different methods and using apparatus of varying effectiveness. Consequently, it may be found that some of these fluid modification elements are more effective than others, and their effectiveness may vary in different situations. For example, a system having only a water injector **508** and plasma electrodes **512** can be effective without any other elements. Alternatively, the helical coil **516** may be found more effective than the torroid coil **520**, and thus the latter may be eliminated in a given situation. Other combinations of fluid modification elements can also be provided.

[0112] Another embodiment of a fluid flow enhancer **600** is shown in **FIG. 25**. This embodiment is configured for liquids, and can be used with liquid fuels such as gasoline. In the liquid flow enhancer, the liquid enters through an inlet conduit **602**, which leads to a diverging section **604**. Disposed beyond the diverging section is a pair of transducers **606** that generate ozone, and can be configured like the ultrasonic transducer **514** in the embodiment of **FIG. 22**. These operate to produce ozone in the flowing fluid through mechanical vibration, and also mechanically excite the molecules of the fluid to a higher energy state.

[0113] Wound around the outside of the fluid flow enhancer shell **626** is a helical electrical coil **608** that operates in a manner similar to the helical coil **516** in **FIG. 22**. This coil creates a magnetic field that charges the liquid within the fluid flow enhancer chamber. A resistive element **610**, such as an LED, can also be included in this coil. A torroid coil **612** is also wrapped around the outside of the gas flow enhancer conduit **626**, and operates like the torroid coil **520** in **FIG. 22**. This coil produces a magnetic field to charge the fluid within.

[0114] Disposed further along the length of the fluid flow enhancer conduit **626** is a photonic device **614** like the photonic device **522** in **FIG. 22**, which is exposed to the interior of the conduit via a window or the like. This device exposes the flowing fluid to light energy to produce ozone in the flowing fluid. The photonic device can be a laser or a UV lamp.

[0115] Disposed around the outer shell **626** of the fluid flow enhancer **600** in the region of the inner and outer helical vane assembly **616** is a high voltage gas plasma chamber **618**. This gas plasma chamber operates on the same principles and for the same purposes as the gas plasma chamber **526** in **FIG. 22**. The gas plasma chamber includes an outer shell that is enclosed on each end so as to create an enclosed annular chamber against the outside of the shell of the gas flow enhancer. The annular chamber is filled with a noble gas and operates on a principle similar to that of neon lights. Disposed within the annular chamber is a charging device **620** that provides an electrical charge to the gas. The charged gas envelopes the gas flow enhancer shell, and thus spreads or distributes the charge along the entire length of the gas plasma chamber shell. This charges the tube in that region, and thus also charges the gas flowing therein.

[0116] Provided in **FIG. 26** is a schematic diagram of an engine system provided with a fluid flow enhancer **500** in the air intake and a fluid flow enhancer **600** in the fuel system, and a mixer **652** for preliminarily mixing a portion of the treated air and fuel prior to introduction into the engine. Intake air, represented by arrow **501**, enters the air intake fluid flow enhancer **500**, is treated by the various modification elements, and then flows into the engine **650**, as represented by arrow **658**. Similarly, liquid motor fuel, represented by arrow **660**, enters the liquid fluid flow enhancer unit **600**, and after being modified, flows to the engine **650** as represented by arrow **662**. The treated fuel can be introduced into the engine in any suitable manner, such as via fuel injectors (not shown), via a carburetor, or any other method.

[0117] The air intake fluid flow enhancer **500** can include a diverter valve **664** that diverts a portion of the intake air flow, as represented by arrow **666**, to a mixing device **652**. The liquid fluid flow enhancer unit **600** can likewise include a diverter valve **668** which diverts a portion of the liquid fuel, represented by arrow **670**, to the mixing device. The mixing device can include a mixing chamber through which the intake air flows, with a fuel injector to inject the treated fuel into the turbulent flowing treated air. One commercially available device that has been used is a high pressure fuel rail that is commonly used in a variety of engines. The air-fuel mixture is then introduced to the engine **650**, as represented by arrow **672**. The relative proportions of air and fuel that are diverted to the mixing device can vary from 0% to 100%. The pre-mixed air and fuel can be more reactive, with a greater degree of vaporization of the fuel, which leads to more complete combustion.

[0118] An additional element that can be incorporated into the system of **FIG. 26** is a turbocharger. For example, the ionizing gas flow enhancer **500** can be disposed downstream of a turbocharger device **674***a*, such that the intake gas stream **501** comprises pressurized air from the turbocharger. Alternatively, a turbocharger **674***b* can be disposed in the outlet stream **658** from the ionizing gas flow enhancer. As yet another alternative, the outlet stream **672** from the mixing device **652** can flow into a turbocharger **674***c* so that the air/fuel mixture is further pressurized prior to introduction into the engine **650**. It will be apparent that other configurations can also be devised to incorporate the benefits of a turbocharger into the ionizing fluid flow enhancer system.

[**0119**] The ionizing fluid flow enhancer has a number of industry applications including industries using internal combustion such as power plants, agriculture, heating, transportation including vehicles, trucks, ships, trains and airplanes. For intake air for internal combustion applications, the extra oxidizing oxygen produces an oxidizing plasma to facilitate more complete combustion, resulting in increased power and significantly lower emissions. The air intake conditioning of an internal combustion process results in increased fuel efficiency and reduced emissions. Similar benefits are realized when liquid fuel is similarly treated prior to introduction into an engine. The inventors have installed the ionizing fluid flow enhancer in a variety of configurations, for both air and fuel intake and exhaust outflow, on a variety of vehicles, including gasoline and diesel engines. These installations have produced noticeable improvements in fuel efficiency, emissions, operating temperatures, and other benefits. When a vehicle is provided with one or more ionizing fluid flow enhancers for the engine intake air and fuel intake, and also includes fluid flow enhancers in the exhaust system for improving gas flow therein, fuel efficiency and other benefits only increase.

[**0120**] It is to be understood that the above-referenced arrangements are illustrative of the application of the principles of the present invention. It will be apparent to those of ordinary skill in the art that numerous modifications can be made without departing from the principles and concepts of the invention as set forth in the claims.

What is claimed is:

1. An ionizing fluid flow enhancer for a fluid conduit of a combustion engine, comprising:

a) a housing having an inlet configured to receive an inlet flow of fluid;

b) at least one fluid modification element, disposed along the housing, configured to chemically alter the flowing fluid; and

c) a spiral vane assembly, configured to produce an outer helical flow of the fluid and an inner helical flow of the fluid within the housing, the spiral vane assembly including

i) a plurality of outer vanes, disposed around an outer periphery of the housing, configured to produce an outer helical flow of the fluid;

ii) a plurality of inner vanes, disposed within a central portion of the housing, configured to produce an inner helical flow of the fluid, the inner helical flow having a higher velocity than the outer helical flow; and

iii) a flow separator, disposed between the inner vanes and the outer vanes, configured to separate the fluid flow into outer flow that flows past the outer vanes, and inner flow that flows past the inner vanes.

2. An ionizing fluid flow enhancer in accordance with claim 1, wherein the fluid is substantially a gas, and further comprising a plasma chamber, disposed within the housing, including a plurality of electrodes, configured to produce an electrical discharge to chemically alter the flowing fluid.

3. An ionizing fluid flow enhancer in accordance with claim 2, wherein the plurality of electrodes are selected from the group consisting of automotive spark plugs, and separate anode/cathode pairs arranged to produce an electrical discharge therebetween.

4. An ionizing fluid flow enhancer in accordance with claim 2, wherein the plurality of electrodes comprise from four to eight electrodes.

5. An ionizing fluid flow enhancer in accordance with claim 2, wherein the plurality of electrodes are disposed in a substantially circular configuration about a perimeter of a cross-section of the plasma chamber region.

6. An ionizing fluid flow enhancer in accordance with claim 2, wherein the inlet conduit interconnects an intercooler of a turbocharger system with an air intake of a combustion engine.

7. An ionizing fluid flow enhancer in accordance with claim 1, wherein the fluid is a liquid motor fuel.

8. An ionizing fluid flow enhancer in accordance with claim 1, wherein the fluid modification element is selected from the group consisting of a water injector configured to inject water vapor into the fluid flow, a plasma electrode configured to produce an electrical discharge in the fluid flow, an ultrasonic transducer configured to mechanically vibrate within the fluid flow, a helical electric coil disposed around an outside of the housing, a torroid electric coil disposed around the outside of the housing, a photonic device configured to expose the flowing fluid to light energy, and a gas plasma chamber configured to produce a gas plasma in contact with a region of the outside of the housing.

9. An ionizing fluid flow enhancer in accordance with claim 8, wherein the water injector is disposed in a restricted flow region adjacent to the inlet, and is.

10. An ionizing fluid flow enhancer in accordance with claim 8, wherein the photonic device is selected from the group consisting of a UV lamp and a UV laser.

11. An ionizing fluid flow enhancer in accordance with claim 8, wherein the gas plasma chamber comprises an annular jacket surrounding the housing in a region adjacent to the spiral vane assembly.

12. An ionizing fluid flow enhancer for a liquid, comprising:

a) a housing, configured to receive a flow of fluid, having an inlet, a diverging section, a central section of substantially constant cross-section, and a converging section;

b) at least one fluid modification element, disposed along the central section of the housing, configured to chemically alter the flowing fluid; and

c) a spiral vane assembly, configured to produce an outer helical flow of the fluid and an inner helical flow of the fluid within the housing, the spiral vane assembly including

i) a plurality of outer vanes, disposed around an outer periphery of the housing, configured to produce an outer helical flow of the fluid;

ii) a plurality of inner vanes, disposed within a central portion of the housing, configured to produce an inner helical flow of the fluid, the inner helical flow having a higher velocity than the outer helical flow; and

iii) a flow separator, disposed between the inner vanes and the outer vanes, configured to separate the fluid flow into outer flow that flows past the outer vanes, and inner flow that flows past the inner vanes

13. An ionizing fluid flow enhancer in accordance with claim 12, wherein the fluid modification element is selected from the group consisting of an ultrasonic transducer configured to mechanically vibrate within the fluid flow, a helical electric coil disposed around an outside of the housing, a torroid electric coil disposed around the outside of the housing, a photonic device configured to expose the flowing fluid to light energy, and a gas plasma chamber configured to produce a gas plasma in contact with a region of the outside of the housing.

14. An ionizing fluid flow enhancer in accordance with claim 12, wherein the photonic device is selected from the group consisting of a UV lamp and a UV laser.

15. An ionizing fluid flow enhancer in accordance with claim 12, wherein the gas plasma chamber comprises an annular jacket surrounding the housing in a region adjacent to the spiral vane assembly.

16. An ionizing fluid flow enhancer in accordance with claim 12, wherein the spiral vane assembly is disposed toward the converging section.

17. A combustion engine system, comprising:

a combustion engine, having an intake manifold for receiving combustion air, and a fuel intake system for receiving fuel;

an air intake conduit, in fluid communication between the intake manifold and atmosphere, having an ionizing gas flow enhancer, comprising:

a) a housing having an inlet configured to receive an inlet flow of fluid;

b) at least one fluid modification element, disposed along the housing, configured to chemically alter the flowing fluid; and

c) a spiral vane assembly, configured to produce an outer helical flow of the fluid and an inner helical flow of the fluid within the housing, , the spiral vane assembly including

i. a plurality of outer vanes, disposed around an outer periphery of the housing, configured to produce an outer helical flow of the fluid;

ii. a plurality of inner vanes, disposed within a central portion of the housing, configured to produce an inner helical flow of the fluid, the inner helical flow having a higher velocity than the outer helical flow; and

iii. a flow separator, disposed between the inner vanes and the outer vanes, configured to separate the fluid flow into outer flow that flows past the outer vanes, and inner flow that flows past the inner vanes; and

a fuel line, in fluid communication between a liquid fuel source and the fuel intake system, having an ionizing liquid flow enhancer, comprising:

a) a housing, configured to receive a flow of fluid from the fuel source, having an inlet, a diverging section, a central section of substantially constant cross-section, a converging section, and an outlet leading to the fuel intake system;

b) at least one fluid modification element, disposed along the central section of the housing, configured to chemically alter the flowing fluid; and

c) a spiral vane assembly, configured to produce an outer helical flow of the fluid and an inner helical flow of the fluid within the housing, the spiral vane assembly including

i) a plurality of outer vanes, disposed around an outer periphery of the housing, configured to produce an outer helical flow of the fluid;

ii) a plurality of inner vanes, disposed within a central portion of the housing, configured to produce an inner helical flow of the fluid, the inner helical flow having a higher velocity than the outer helical flow; and

iii) a flow separator, disposed between the inner vanes and the outer vanes, configured to separate the fluid flow into outer flow that flows past the outer vanes, and inner flow that flows past the inner vanes.

18. A combustion engine system in accordance with claim 17, further comprising:

a first diverter valve, disposed in the ionizing gas flow enhancer, configured to divert at least a portion of flow from the gas flow enhancer to a mixer;

a second diverter valve, disposed in the ionizing liquid flow enhancer, configured to divert at least a portion of flow from the liquid flow enhancer to a mixer; and

a mixer, in fluid communication with the intake manifold, configured to receive the diverted flows from the first and second diverter valves, and to produce an air/fuel mixture and introduce the air/fuel mixture to the intake manifold.

19. A combustion engine system in accordance with claim 17, wherein the fluid modification element of the gas flow enhancer and of the liquid flow enhancer is selected from the group consisting of a water injector configured to inject water vapor into the fluid flow, a plasma electrode configured to produce an electrical discharge in the fluid flow, an ultrasonic transducer configured to mechanically vibrate within the fluid flow, a helical electric coil disposed around an outside of the housing, a torroid electric coil disposed around the outside of the housing, a photonic device configured to expose the flowing fluid to light energy, and a gas plasma chamber configured to produce a gas plasma in contact with a region of the outside of the housing.

20. A combustion engine system in accordance with claim 17, wherein the gas flow enhancer is disposed downstream of an intercooler of a turbocharger system associated with the combustion engine.

* * * * *