

[54] **FLUID IONIZATION**

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[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. Nos. 827,451, April 23, 1969, Pat. No. 3,554,443, and Ser. No. 85,911, Nov. 2, 1970, abandoned.

[52] U.S. Cl. **239/102, 239/DIG. 20**

[51] Int. Cl. **B05b 3/14**

[58] Field of Search **239/102, 103, 101, 239/DIG. 20; 116/137**

[56] **References Cited**

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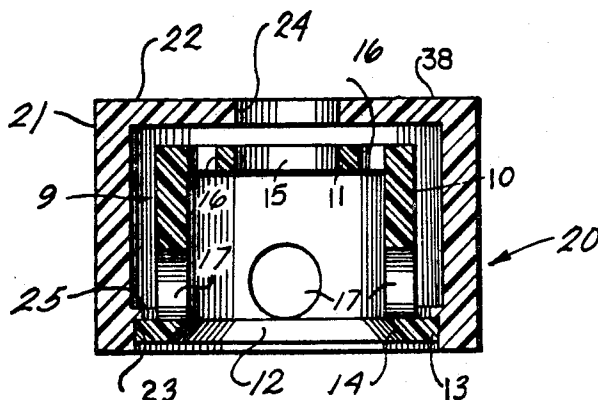
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Primary Examiner—Lloyd L. King
Attorney—Robert L. Parker et al.

[57] **ABSTRACT**

Pressure waves and ionization are produced by an energizing cell that is preferably made from a dielectric material such as Teflon. The cells are disclosed in several different configurations that serve to increase the level of ionization. A mixture is highly ionized by energizing one or more of its components prior to the formation of the mixture. If all the components are not separately energized, the mixture as a whole is energized after its formation. Important applications of the invention are in a paint sprayer and in an internal combustion engine, where engine emissions are reduced and engine performance is improved.

6 Claims, 12 Drawing Figures



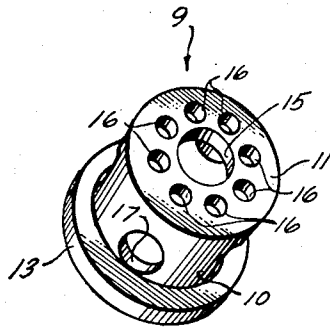


FIG. 1B

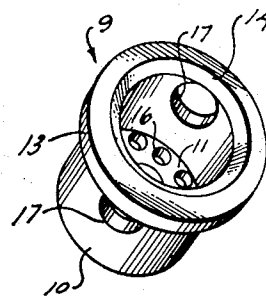


FIG. 1C

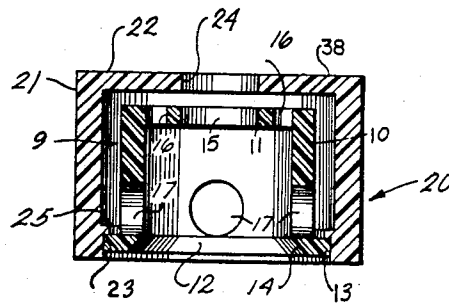


FIG. 1A

FIG. 2A

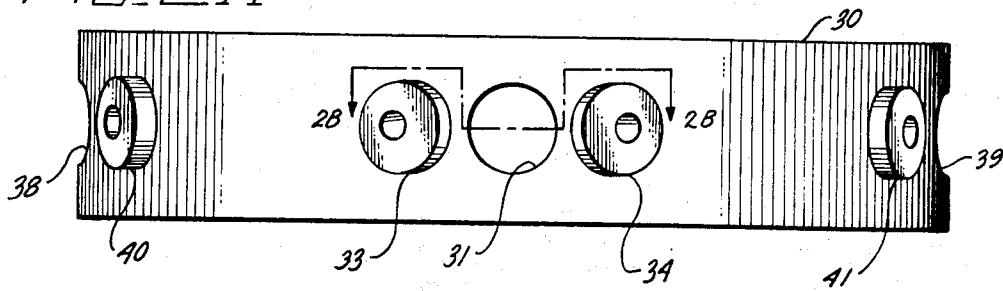


FIG. 2B

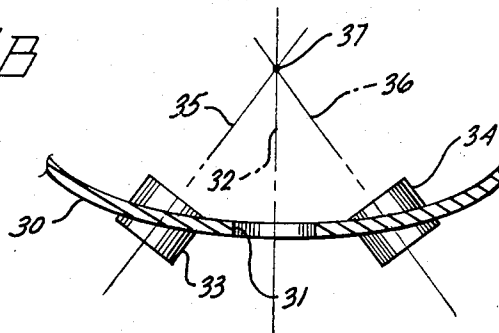


FIG. 5

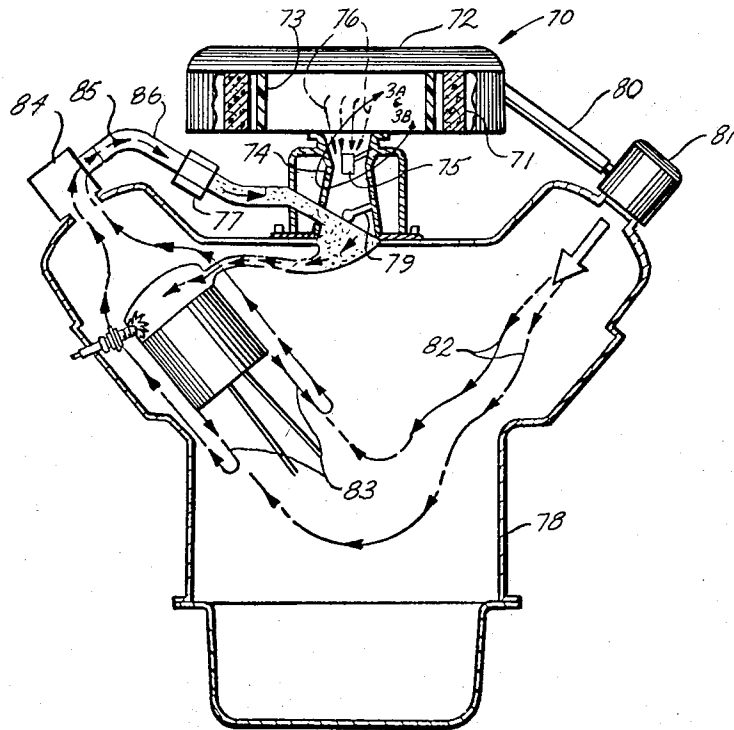


FIG. 3A

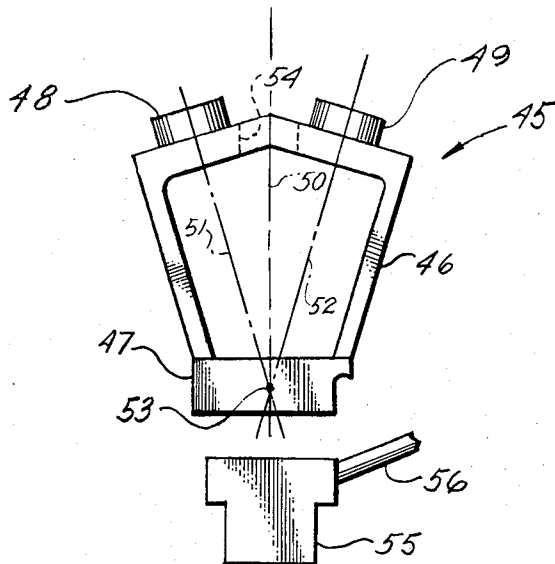


FIG. 3B

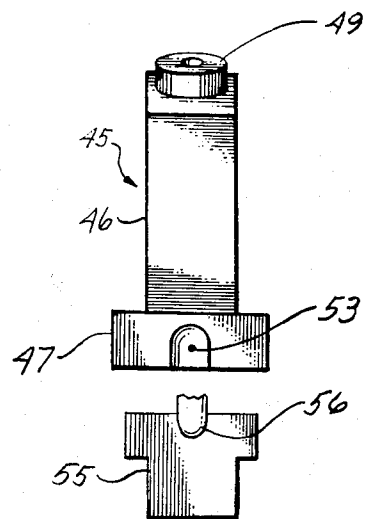


FIG. 4A

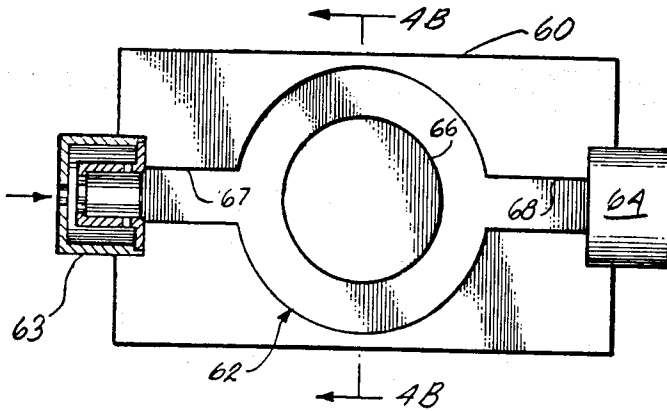


FIG. 4B

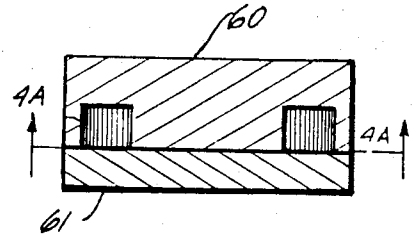


FIG. 6

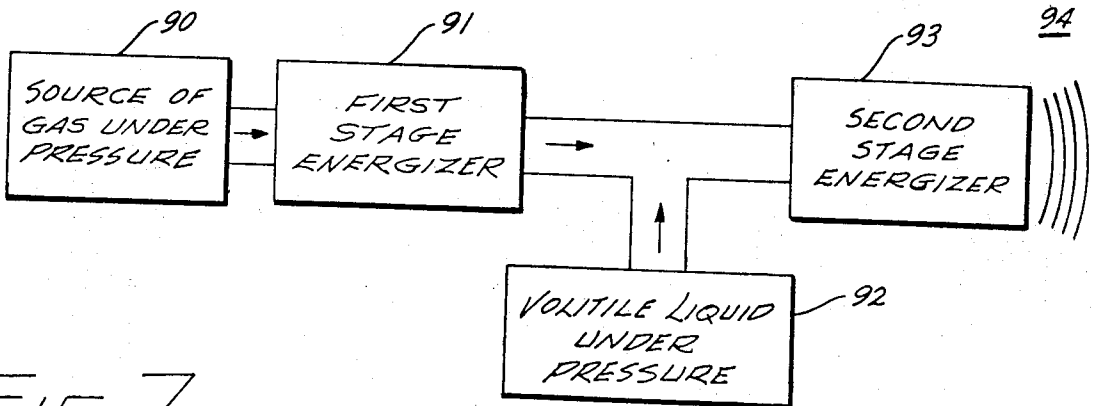
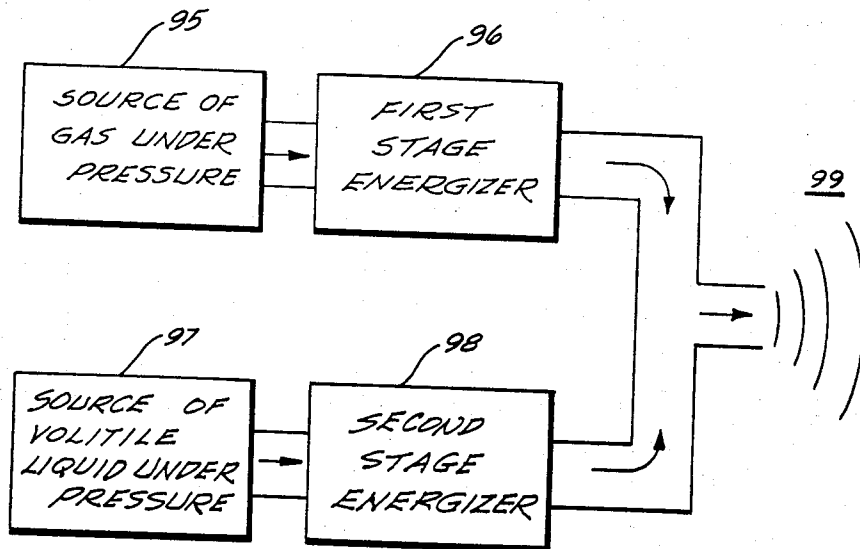


FIG. 7



FLUID IONIZATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of the following applications: Ser. No. 827,451, filed April 23, 1969 (U.S. Pat. No. 3,554,443); Ser. No. 85,911, filed Nov. 2, 1970, and claiming the filing date of Ser. No. 827,451; Ser. No. 82,771, filed Oct. 21, 1970; Ser. No. 158,915, filed July 1, 1971; Ser. No. 189,206, filed Oct. 14, 1971; and Ser. No. 217,124, filed Jan. 12, 1972.

BACKGROUND OF THE INVENTION

This invention relates to fluid ionization and, more particularly, to the ionization of mixtures involved in chemical processes, such as internal combustion or paint spraying.

My U.S. Pat. No. 3,554,443, which issued Jan. 12, 1971, discloses an energizing cell that has been observed to produce pressure wave energy having a high intensity and a long propagating range. My copending applications, Ser. No. 111,995, Ser. No. 189,206, and Ser. No. 217,124, disclose various arrangements of this energizing cell that increase the intensity and/or propagating range of the pressure wave energy. My application Ser. No. 158,915 discloses that the use of various arrangements of this energizing cell in the intake system of an internal combustion engine reduces all three major engine emissions and improves engine performance.

SUMMARY OF THE INVENTION

The present invention is based upon the discovery that the energizing cell disclosed in my U.S. Pat. No. 3,554,443 produces substantial ionization, in addition to pressure waves. In general, it is believed that the ionization is produced by forming a fluid stream, reducing the cross-sectional area of a portion of the stream, and subjecting the reduced portion of the stream to high shear forces. It is further believed that this ionization is reinforced by mixing with the fluid stream, fluid that has passed through holes having a characteristic frequency related to the characteristic frequency of the shock waves associated with the stream. Consistent with the ionizing capability of the energizing cell, it has been discovered that a higher level of ionization and more pressure wave energy are produced when the cell is made from a dielectric material such as Teflon.

It has further been discovered that a mixture can be more highly ionized by energizing one or more of the components of the mixture prior to its formation. If all the components of the mixture are not energized prior to its formation, then the mixture itself is also energized. The ionization produced by the invention is particularly effective in an internal combustion engine where it reduces all three major engine emissions and improves engine performance. It appears that an entirely new and different environment for internal combustion is created. When the air and fuel in the intake system of an internal combustion engine are energized, the nitrogen and oxygen molecules of the air become positively ionized and the fuel molecules become negatively ionized. As a result, a more homogeneous airflow mixture is produced, the desired chemical combinations for stoichiometric burning are promoted, and the unwanted chemical combinations for engine emissions are inhibited. Engine performance is relatively insensi-

tive to spark timing, and the maximum reduction of engine emissions is achieved when the spark timing is set at a slightly advanced from the top dead-center piston position.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of specific embodiments of the best mode contemplated for carrying out the invention are illustrated in the drawings, in which:

FIGS. 1A, 1B, and 1C are, respectively, a side elevation view in section of an energizing cell, a perspective view of the cell insert from upstream, and a perspective view of the cell insert from downstream;

FIGS. 2A and 2B are, respectively, a side elevation view and a partial, top sectional view of one effective arrangement of the energizing cells of FIG. 1;

FIGS. 3A and 3B are, respectively, a front elevation view and a side elevation view of another effective arrangement of the energizing cells of FIG. 1;

FIGS. 4A and 4B are, respectively, a top sectional view and a side sectional view of another effective arrangement of the energizing cells of FIG. 1;

FIG. 5 is a schematic diagram of an internal combustion engine depicting the locations of the arrangements of FIGS. 2 through 4 within the engine;

FIG. 6 is a schematic block diagram of a system for energizing a material with the arrangements of FIGS. 2 through 4; and

FIG. 7 is a schematic block diagram of another system for energizing a material with the arrangements of FIGS. 2 through 4.

DETAILED DESCRIPTION OF THE SPECIFIC EMBODIMENTS

The disclosures of the following applications are incorporated herein by reference: Ser. No. 827,451, filed Apr. 23, 1969 (U.S. Pat. No. 3,554,443); Ser. No. 158,915, filed July 1, 1971; Ser. No. 189,206, filed Oct. 14, 1971; and Ser. No. 217,124, filed Jan. 12, 1972.

In FIGS. 1A, 1B, and 1C, a cylindrical insert 9 is shown. Insert 9 has a cylindrical side wall 10 and, at its upstream end, a circular end wall 11. At its downstream end, insert 9 has an outlet opening 12 and an outwardly extending flange 13. A countersink 14 circumscribes outlet opening 12. End wall 11 has a large center hole 15 and a plurality of smaller holes 16 arranged in oppositely disposed pairs in a circle about hole 15. Side wall 10 has a plurality of holes 17 arranged at 90° intervals near outlet opening 12. A cover 20, which has a cylindrical side wall 21, a circular upstream end wall 22, and a circular downstream opening 23, surrounds insert 9. End wall 22 has a center inlet hole 24 aligned with hole 15 of insert 9. The inside surface of side wall 21 has an annular shoulder 25 near opening 23. Flange 13 forms a press fit with the inside surface of side wall 21 and abuts shoulder 25. The dimensions of insert 9 and cover 20 are preferably the same as the dimensions set forth in my U.S. Pat. No. 3,554,443, which issued Jan. 12, 1971, except for hole 24, which preferably has a diameter equal to that of hole 15.

As described in my U.S. Pat. No. 3,554,443, when a pressure drop is established from hole 24 to opening 12, fluid entering the cell from hole 24 flows through holes 15, 16, and 17 to opening 12. The fluid flowing through hole 15 to opening 12 forms a core stream. The fluid flowing through holes 16 forms a sheath be-

tween the core stream and the inside surface of side wall 10. The fluid flowing through holes 17 constricts the core stream. Thus, the fluid flowing through holes 16 and 17 forms around the core stream a converging-diverging boundary layer that accelerates the core stream to supersonic velocity as the core stream emerges from opening 12. When the supersonic core stream encounters the ambient fluid medium adjacent to outlet opening 12, shock waves are produced. An energizing cell having the dimensions stated in my U.S. Pat. No. 3,554,443 produces core stream shock waves in the range of 0.170 inches to 0.195 inches depending upon pressure. For example, the pressures encountered in the intake system of an internal combustion engine result in an average wavelength of about 0.174 inches.

Fluid passing through a hole has associated with it pulsations at a characteristic wavelength that is directly related to the hole diameter and inversely related to the fluid velocity. The diameters of holes 15, 16, 17, and 24 are selected so the characteristic wavelengths of the pulsations associated with them are multiples or sub-multiples of the wavelength of the shock waves produced by the core stream within about 10 percent. For example, the diameter of holes 15 and 24 could be 0.177 inches, the diameter of hole 16 could be 0.0315 inches, and the diameter of hole 17 could be 0.093 inches. Thus, the resultant pressure wave energy is coherent in that it comprises one or more pressure wave components at wavelengths that are multiply related. The pulsations characteristic of holes 15, 16, 17, and 24, and the shock waves produced by the core stream, reinforce each other due to their multiple wavelength relationship, and the level of the energy emanating from outlet 12 is enhanced. The energy level is further enhanced by resonant action taking place between the inside surface of end wall 22 and the surface of flange 13, which define an annular resonant cavity. The resonant cavity is dimensioned to resonate at the shock wave wavelength of the core stream.

In general, when the relationship between wavelength and dimensions stated in this specification are met within about ± 10 percent, the desired results are achieved. Beyond ± 10 percent the results drop off but remain useful for some purposes.

Recently, it has been discovered that the described energizing cell ionizes a fluid passing through it, in addition to producing pressure waves in such fluid. The ionizing capability of the energizing cell has been demonstrated by the following experiments:

1. Pressurized air of 1 psig or greater was coupled to hole 24 and outlet opening 12 was exposed to atmospheric pressure. A significant level of ionization was detected in the air emanating from outlet opening 12 with an ionization field scanner manufactured by Scientific Enterprises, Inc., 2750 Industrial Lane, Broomfield, Colorado 80020.
2. Pressurized air of 1 psig or greater was coupled to inlet hole 24 as in Experiment 1, and a material was mixed with the air emanating from outlet opening 12. When certain materials were used, such as volatile liquid, talc, and aluminum filings, a much higher level of ionization (about 15 times higher) was detected than the level of ionization in Experiment 1. In addition, the detected ionization had the opposite polarity from the detected ionization in Experiment 1. When other materials were used,

such as kerosene or water, negligible ionization was detected.

3. Experiments 1 and 2 were repeated and the pressure of the air coupled to the energizing cell was varied up to 100 psig. It was observed that the level of ionization was directly related to the pressure, the higher the pressure the greater the ionization.
4. Experiments 1 and 2 were repeated, a copper screen was placed six to 12 inches from outlet opening 12 in the path of the air emanating from outlet opening 12, and the screen was connected to ground through an ammeter. When Experiment 1 was repeated with the screen, a slight electric current in the microampere range flowing from the screen to ground was detected by the ammeter, i.e., there was a flow of electrons from ground to the screen. This would indicate that the ionized air molecules have a positive charge. When Experiment 2 was repeated with the screen, using a volatile liquid, talc, or aluminum filings, a current of an order of magnitude larger flowing from ground to the screen was detected by the ammeter, i.e., there was a flow of electrons from the screen to ground. This would indicate that the ionized particles of the material mixed with the air has a negative charge.

The fluid flowing through holes 17 impinges upon the core stream and exerts thereon a large shear force. Since the core stream has a small cross-sectional diameter at this point, the shear force is concentrated in a small area. It is believed that this shear force is the principal cause for the ionization produced by the energizing cell, i.e., that the force of the fluid flowing through holes 17 shears electrons from the molecules of the fluid flowing in the core stream; the process is supplemented by similar ionization of the fluid passing through holes 15, 16, 17, and 24; and the coherent nature of the pressure waves produced by the energizing cell enhances the level of ionization by aligning the ionized molecules of the fluid to reinforce the resultant ionization.

The pressure waves produced by the energizing cell have a surprisingly long propagating range in comparison with other types of pressure wave generators. The range of the ionization produced by the energizing cell appears to be comparable to the propagating range of the pressure waves. It is known that coupling can take place between electric waves, such as magneto-hydrodynamic waves and sound waves in an ionized medium. (See, for example, the text, "Electrodynamics of Particles and Plasmas," P. C. Clemmow and J. P. Dougherty, Addison-Wesley Publishing Company, 1969, which is incorporated herein by reference.) It is further known that when fluid molecules change rotational energy states they absorb or emit energy waves having wavelengths in the range of 0.1 mm to 1.0 cm; the wavelengths of the pressure waves produced by the energizing cell lie within this range. In view of these facts, it is believed the long propagating range of the pressure waves and ionization produced by the energizing cell results from an energy interchange between, and a mutual reinforcement by, the pressure wave energy and the ionization energy.

In the past, the energizing cells have been made from a metal such as aluminum. Recently it has been discovered that significantly more pressure wave energy and ionization is produced by an energizing cell made from a dielectric material, such as Teflon. This discovery is

consistent with the fact that the energizing cell produces ionization. It is believed that more ionization is produced by an energizing cell made from a dielectric rather than a metal, i.e., an electrical conductor, because the charged particles passing through the energizing cell do not leak off into the material from which the cell is constructed, as with a metallic cell. Further, it is believed that the contact and friction between the moving fluid and the dielectric surface of the cell increases the ionization by static charging in analogous fashion to the charging of a rubber rod with a catskin.

In FIGS. 2A and 2B one arrangement of a number of the energizing cells of FIG. 1 is shown in an annular baffle 30. Typically, baffle 30 has about a six inch inside diameter and is made from a plastic sheet about 3/16 of an inch thick. Baffle 30 has a hole 31 disposed about an axis 32. Energizing cells 33 and 34, which are identical to the cell of FIG. 1 and made of Teflon, fit through angled holes in baffle 30. Cells 33 and 34 are disposed about axes 35 and 36, respectively, which intersect axis 32 at a point 37. The inlet holes of cells 33 and 34 are disposed outside baffle 30 and the outlet openings of cells 33 and 34 are disposed inside baffle 30 so as to emit shock waves along axes 35 and 36, respectively. The distance from the outlet opening of cell 33 along axis 35 to point 37, the distance from hole 31 along axis 32 to point 37, and the distance from the outlet opening of cell 34 along axis 36 to point 37 are equal to each other and are, preferably, a multiple of the wavelength of the shock waves produced by cells 33 and 34; for example, these distances could be 1.732 inches. The diameter of hole 31 is also preferably a multiple of the shock wave wavelength; for example, 0.516 inches, 0.680 inches, or 0.860 inches. The angle between axes 32 and 35 and between axes 32 and 36 is typically in the range of $19\frac{1}{2}^{\circ}$ to 23° . In any case, best results are obtained if this angle is approximately equal to the Mach angle of the chevron-shaped shock waves; thus, preferably this angle is inversely related to the Mach number of the air leaving the outlet opening of the cells. Three other energizing sets each comprising a hole similar to hole 31 and cells similar to cells 32 and 33 are distributed at 90° intervals around baffle 30. Two of these holes designated 38 and 39, and two of these cells designated 40 and 41, are depicted in FIG. 2A. If more air is required by the engine, more sets of energizing sets could be distributed around baffle 30; for example, six sets might be advantageous for automotive applications.

In operation, when a pressure drop is established from the outside of baffle 30 to its inside, air or other fluid passes through hole 31 and cells 33 and 34. The shock waves and ionized air produced by cells 33 and 34 mix with the air stream flowing through hole 31 at point 37. It has been observed that the intensity of the resultant shock waves and the level of the resultant ionization downstream of point 37 are substantially greater than the shock wave intensity and ionization level attributable to the sum of cells 33 and 34. This may be due to a change in the rotational energy state of the fluid molecules as they impinge upon each other at point 37, or it may be due to the shear forces exerted on the air molecules by the chevron-shaped shock waves produced by cells 33 and 34 as they draw close to point 37. (It is to be noted that the adjacent sides of the chevron-shaped shock waves from cells 33 and 34 are approximately parallel to axis 32, if the Mach angle

of the shock waves at the Mach numbers encountered is approximately equal to the angle between axes 32 and 35 and the angle between axes 32 and 36.)

In addition to essentially complete energization of the air flowing through the energizing sets, the arrangement of FIG. 2 has an additional major advantage, namely, that the holes (e.g., 31, 38, and 39) permit more air to flow as the pressure drop increases over the range of operation. In other words, although there is supersonic flow through the energizing cells (e.g., 33, 34, 40, and 41), flow through the holes is not choked. In the environment of an internal combustion engine, where this arrangement is placed in the air cleaner, as discussed below in connection with FIG. 5, the interaction of the holes and the energizing cells is particularly important because the unchoked flow through the holes permits sufficient air to flow into the carburetor to fulfill the engine needs at high acceleration; the large amount of air flowing through each of the holes continues to be energized by the convergence of shock waves from the adjacent cells at the point of intersection (e.g., 37). On the other hand, at idle and other low vacuum conditions most of the air bypasses the holes and is energized directly by passage through the cells.

In FIGS. 3A and 3B another arrangement of a number of the energizing cells of FIG. 1 is shown in a bracket 45. Bracket 45 has a four-sided frame 46 that is joined to a circular clip 47. Energizing cells 48 and 49, which are identical to the cells of FIG. 1 and preferably made of Teflon or other dielectric material, fit through angled holes in the upper sides of frame 46, as shown in the drawings. Bracket 45 is symmetrical about an axis 50. Cells 48 and 49 are disposed about axes 51 and 52, respectively, which intersect axis 50 at a point 53. The inlet holes of cells 48 and 49 face away from point 53 and the outlet openings of cells 48 and 49 face toward point 53. Typically, the angle between axis 51 and axis 50 and between axis 52 and axis 50 is 16.8° . This angle is typically smaller than the angle in the arrangement of FIG. 2 because, as discussed below in connection with FIG. 5, the arrangement of FIG. 3 is contemplated for use in a carburetor of an internal combustion engine, where a higher air velocity would be found than in the air cleaner, where use of the arrangement of FIG. 2 is contemplated. Frame 46 has an opening 54 between cells 48 and 49. The distance from the outlet opening of cell 48 along axis 51 to point 53, the distance from the outlet opening of cell 49 along axis 52 to point 53 are equal to each other and are preferably a multiple of the wavelength of the shock waves produced by cells 48 and 49; for example, these distances could be 1.548 inches. When a pressure drop is established from the inlet hole to the outlet opening of cells 48 and 49, the arrangement of FIG. 3 essentially operates in the same manner as the arrangement of FIG. 2. The air or other fluid passing through opening 54 mixes with the shock waves and ionized molecules produced by cells 48 and 49 at point 53. The intensity of the resultant shock waves and the resultant level of ionization are substantially greater than that attributable to the sum of cells 48 and 49.

In FIGS. 4A and 4B another arrangement of a number of the energizing cells of FIG. 1 is shown in connection with rectangular plates 60 and 61, which are clamped together by means not shown. A network 62 of channels formed in plate 60 couples the outlet opening of an energizing cell 63, which is affixed to one end

of plate 60, to the inlet hole of an energizing cell 64, which is affixed to the other end of plate 60. Cells 63 and 64 and plates 60 and 61 are all preferably made from a dielectric material such as Teflon or another plastic material. As illustrated in FIG. 4A, network 62 comprises a circular channel 66 and straight channels 67 and 68 extending from opposite sides of channel 66 to the exterior of plate 60. Channels 66, 67, and 68 all have square cross sections with a side dimension that is preferably equal to the wavelength of the shock waves, e.g., 0.174 inches. The outer diameter of circular channel 66 is preferably a multiple of the wavelength of the shock waves, e.g., 0.870 inches. The lengths of straight channels 67 and 68 between cells 63 and 64, respectively, and the perimeter of circular channel 66 are also preferably multiples of the wavelength of the shock waves, e.g., 0.348 inches. Channels 66, 67, and 68 could be formed by grinding a groove out of the surface of plate 60 adjacent to plate 61, or by molding.

When a pressure drop is established from the inlet hole of cell 63 to the outlet opening of cell 64, air or other fluid flows through cell 63, network 62, and cell 64. The coherency of the pressure wave energy leaving cell 63 and, thus, the level of ionization are increased by network 62, which functions as a resonant cavity. The level of ionization is further increased by cell 64. In general, it has been observed that the use of a network of channels having a square cross section, such as network 62, significantly increases the level of ionization produced by an energizing cell of the type shown in FIG. 1. It has further been observed that the use of two such cells in series significantly increases the level of ionization. The arrangement disclosed in FIG. 4 utilizes both these techniques simultaneously to amplify the level of ionization.

FIG. 5 schematically represents an internal combustion automobile engine in which the arrangements of FIGS. 2 through 4 are installed. The engine has an air cleaner 70 with a paper filter element 71 and a cover 72 that seals the top of element 71 so all the air entering the engine from the atmosphere must pass through it. The arrangement of energizing cells disclosed in FIG. 2, represented as a device 73, is located inside filter element 71 in spaced relationship as illustrated in FIG. 5. Cover 72 also seals the top of the annular baffle of device 73 so all the air from the atmosphere entering the engine must also pass through the energizing cells or the holes of device 73. After all the air entering the engine is energized by device 73, this energized air, represented by arrows 76, passes into a carburetor 74 to be mixed with the fuel. In carburetor 74, the arrangement disclosed in FIG. 3, represented as a device 75, is mounted on the booster venturi. As depicted in FIGS. 3A and 3B, clip 47 fits over the booster venturi designated 55. Clip 47 has a notch that fits around the fuel jet designated 56. Point 53 lies at the exit opening of fuel jet 56 within booster venturi 55. As a result, the energy produced by cells 48 and 49 is focused at the point where the fuel begins to vaporize and mix with the air within carburetor 74.

Although the preferred embodiment involves only device 73 and device 75, the arrangement disclosed in FIG. 4, represented as a device 77, can also be used to advantage in an engine provided with a positive crankcase ventilation (PCV) system, as illustrated in FIG. 5. The combustible crankcase emissions produced within

a crankcase manifold 78 in the course of the operation of the engine, comprise blowby gases, completely combusted substances that escape from the combustion cylinders via the piston rings, and oil particles that become suspended in the air within the crankcase manifold. The PCV system returns these crankcase emissions to the intake system of the engine, at the base of carburetor 74 below a throttle valve 79 for recombustion in the engine. Clean air is coupled from air cleaner 70 by a connecting hose 80 to crankcase manifold 78 through an oil filler cap 81. This clean air, represented by arrows 82, mixes with and carries the blowby gases, represented by arrows 83, out of crankcase manifold 78 through a PCV valve 84, as represented by arrows 85. PCV valve 84 is coupled to the base of carburetor 74 by a connecting hose 86, which serves as the PCV return line. The described PCV system is conventional except for the presence of device 77 in the PCV return line and the provision of a spring having a smaller spring constant for PCV valve 84. This enables PCV valve 84 to operate normally, i.e., to close during idling, despite the smaller pressure drops that have been found to exist in the presence of device 77. To install device 77, hose 86 is simply cut, the upstream end formed by the cut being connected to the inlet hole of cell 63 and the downstream end formed by the cut being coupled to the outlet opening of cell 64.

When devices 73, 75, and/or 77 are utilized in an internal combustion engine in the manner depicted in FIG. 5, the vacuum created in the intake system by the engine operation provides the pressure drop to operate the devices. An air stream induced to flow from the atmosphere to the vacuum created in the intake system is converted by the devices to ionized pressure waves. As a result, all three major engine emissions, namely, hydrocarbons, carbon monoxide, and the oxides of nitrogen, are substantially reduced. Further, engine performance is improved in that the carbon dioxide produced during combustion increases, the fuel consumption drops, and the drivability of the automobile is preserved. In short, the energy produced by devices 73, 75, and/or 77 appears to create a totally new and different environment for combustion in the cylinders of the engine. The fuel is more finely atomized, the air-fuel mixture is more homogeneous, the desired chemical combinations for stoichiometric burning are promoted, the unwanted chemical combinations for emissions are inhibited, and the flame front of the charge in the cylinders appears to move much more rapidly after ignition. The more rapid movement of the flame front after ignition is experimentally supported by the observation that the drivability of the engine is relatively insensitive to variations in the spark timing about the top dead center piston position. In other words, acceptable drivability is obtained for a relatively wide range of settings of spark timing on either side of the top dead center piston position. This permits the spark timing to be set so as to minimize engine emissions without impairing drivability. One manifestation of the promotion of the desired chemical combinations is that the aromatic hydrocarbon emissions are reduced more than the non-aromatic hydrocarbons.

In order to achieve the maximum reduction in all three engine emissions in this new combustion environment, several engine modifications are made. In most cases, the only modifications necessary are that the spark timing is set at idle to top dead center or a 1°

advance, depending upon the automobile, and the vacuum spark advance mechanism is disconnected. Contrary to the reaction in the conventional combustion environment to spark retard, the carbon monoxide level does not rise appreciably and drivability is not impaired. The centrifugal spark advance is not disconnected, i.e., it remains operative. In some cases where only device 73 is employed, it is also advantageous to provide a smaller metering orifice on the fuel jet, to seal the carburetor bowl vent to the atmosphere, and/or to reset the idling mixture adjustment. The latter three modifications are sometimes found to be desirable because device 73 lowers the absolute pressure or the air passing through the carburetor and, thus, tends to draw too much fuel.

It is believed device 73, which energizes the air prior to carburetion, is primarily responsible for the reduction in the oxides of nitrogen by chemically inhibiting their formation. It is further believed device 75, which energizes the fuel leaving the jet, is primarily responsible for reducing hydrocarbons and carbon monoxide and improving performance by promoting stoichiometric burning through ionization and atomization of the fuel. It is further believed device 77, which energizes the crankcase emissions returned to the base of carburetor 74, supplements devices 73 and 75 in reducing all three engine emissions and improving performance. It has been found that the retardation of the spark timing to nominal top dead center does not cause the engine to run hotter or significantly raise the level of carbon monoxide. It is believed the new engine environment described above results in more of the energy generated by combustion being utilized to drive the pistons and in less of this energy being lost to the cylinder walls in the form of nonutilized heat, which tends to produce oxides of nitrogen, or incompletely burned products of combustion.

It is believed that devices 73, 75, and 77 operate in the following way to reduce all three engine emissions and improve engine performance: As the air molecules drawn into the engine pass through devices 73, 75, and/or 77, electrons are separated from the outer shell of these molecules and are captured by fuel molecules in carburetor 74. Consequently, an ionized air-fuel mixture is formed. The oxygen and nitrogen atoms and molecules of the air, having lost electrons, are positively ionized, and the fuel molecules, having gained electrons, are negatively ionized. After a charge of the ionized air-fuel mixture enters the cylinder, it is heated by the compression stroke and the advancing flame front prior to the actual combustion. The heating greatly intensifies the ionization of the air-fuel mixture. The higher the flame temperature in the cylinders, the more the air-fuel mixture is heated and the more the ionization is intensified. Thus, to achieve the best results, the air-fuel ratio and the engine timing are adjusted for maximum flame temperature. During the actual combustion, the ionized oxygen and fuel atoms and molecules, which have opposite polarities, are attracted electrostatically to each other and tend more readily to combine stoichiometrically. As a result, hydrocarbons and carbon monoxide are reduced and carbon dioxide is increased. During the actual combustion, the ionized oxygen and nitrogen atoms and molecules, which have the same polarity, are repelled electrostatically from each other and do not tend to combine chemically to form oxides of nitrogen. A large per-

centage of the nitrogen atoms are so highly ionized prior to the actual combustion as to deplete completely their outer shell of electrons. Thus, these nitrogen atoms are chemically inert, their electron structure appearing as the electron structure of helium atoms. During the actual combustion, the inert nitrogen atoms further tend to resist combination with oxygen to form oxides of nitrogen.

In tests conducted on six different automobiles of the three major American manufacturers, model years 1966-70, the use of device 73 alone plus all the engine modifications mentioned above provided the following average reductions in emissions when the 1972 Federal Cycle (Hot Start) was run: hydrocarbons - 56.8 percent; carbon monoxide - 39.9 percent; and oxides of nitrogen - 55.0 percent. The average increase in carbon dioxide in these tests was 34.3 percent, and no appreciable impairment in drivability was observed. When a steady state road load test at 60 miles per hour was run on these six automobiles, the following average reductions in emissions were achieved: hydrocarbons - 69.7 percent; carbon monoxide - 61.5 percent; and oxides of nitrogen - 80.3 percent.

In tests conducted on a Ford automobile, model year 1970, the use of devices 73 and 75 together plus only the spark timing engine modifications mentioned above provided the following average reductions in emissions when the 1972 Federal Cycle (Hot Start) was run: hydrocarbons - 66.1 percent; carbon monoxide - 14.8 percent; oxides of nitrogen - 46.4 percent. The average increase in carbon dioxide was 40.0 percent, and no appreciable impairment in drivability was observed. When a steady state road load test at 60 miles per hour was run on this automobile, the following average reductions in emissions were achieved: hydrocarbons - 92.0 percent; carbon monoxide - 70.6 percent; and oxides of nitrogen - 78.4 percent.

The intensification of the ionization in the cylinders is one manifestation of a general principle that the level of ionization is intensified and multiplied when the internal energy of the fluid is raised either before or after passage through the energizing cell of FIG. 1. Another manifestation of this principle is the dependence of the level of ionization upon pressure mentioned above in connection with Experiment 3. Still another manifestation of this principle is the increase in the level of ionization produced by two energizing cells in series; the internal energy of the fluid having the first cell is raised by virtue of the ionization.

In FIG. 5 the air is primarily energized by device 73, the fuel is primarily energized by device 75, and the energized air and the energized fuel are combined to form a mixture apparently having a higher level of ionization than a mixture energized after combination of the air and fuel. The principle that a mixture can be more highly ionized when one or both of the components are separately energized prior to combination is applicable in processes other than internal combustion. In FIG. 6, a source 90 of gas under pressure is coupled to the inlet of a first stage energizer 91, which could be the arrangement disclosed in FIG. 4. A source 92 of a volatile liquid under pressure and the outlet of energizer 91 are coupled to the inlet of an energizer 93, which could also be the arrangement of FIG. 4 or the nozzle arrangement disclosed in my U.S. Pat. No. 3,618,863, which issued Nov. 9, 1971. The gas from source 90 is first energized by energizer 91 and then combined with

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the volatile liquid from source 92 to form a mixture that is energized by energizer 93. The energized mixture, represented by reference numeral 94, emanates from energizer 93 with a high level of ionization. As an alternative to the embodiment of FIG. 6, sources 90 and 92 could be exchanged, the volatile liquid being energized by energizer 91 and the gas being combined with the energized volatile liquid. A further alternative is shown in FIG. 7. A source 95 of gas under pressure is coupled to the inlet of a first stage energizer 96, and a source 97 of volatile liquid under pressure is coupled to the inlet of a second stage energizer 98. The outlets of energizers 96 and 98 are coupled together. The gas from source 95 is separately energized by energizer 96, the volatile liquid from source 97 is separately energized by energizer 98, and the energized gas and the energized volatile liquid are combined to form a highly ionized mixture, represented by reference numeral 99. An important application of the arrangements of FIGS. 6 and 7 is as a paint sprayer, the gas being air and the volatile liquid being paint. The invention contemplates various modifications of the arrangements disclosed in FIGS. 6 and 7. For example, talc, aluminum filings, or other ionizable materials could be substituted for the volatile liquid and other fluids could be substituted for the gas. Further, energizers 91, 93, 96, and 98 could be other types of devices that produce ionization and pressure waves, including the devices disclosed in the applications and patent incorporated herein by reference.

The described embodiments of the invention are only considered to be preferred and illustrative of the inventive concept; the scope of the invention is not to be restricted to such embodiments. Various and numerous other arrangements may be devised by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. An energizing cell comprising:

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a body member made of a dielectric material, the body member having a passage through it; means responsive to fluid flow through the cell for forming a core stream of fluid passing through the passage; and means responsive to fluid flowing through the cell for forming a radially converging fluid ring around the core stream to establish a throat in the core stream where the core stream travels at sonic velocity and accelerates to supersonic velocity downstream of the throat.

2. The cell of claim 1, in which the means for forming a core stream of fluid comprises a wall of the body member at one end of the passage, a large center hole formed in the wall, and a plurality of small peripheral holes formed in the wall in a circular arrangement around the large hole.

3. The cell of claim 2, in which the means for forming a converging ring comprises an even plurality of intermediate holes formed in the portion of the body member that defines the passage.

4. The cell of claim 3, in which the diameter of the large hole, the intermediate holes, and the small holes are multiply related.

5. The cell of claim 3, in which the core stream forms shock waves after it leaves the passage and the large hole, the intermediate holes, and the small holes are all dimensioned so their characteristic wavelengths are multiply related to the wavelength of the shock waves.

6. The cell of claim 5, in which the body member includes means for forming a resonant cavity around the portion of the body member that defines the passage, the resonant cavity being coupled to the passage by the large hole, the intermediate holes, and the small holes, the resonant cavity being completely enclosed except for an inlet located adjacent to and aligned with the large hole in the wall.

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