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Bartholomew

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[54] **HIGH EFFICIENCY-LOW POLLUTION EMISSION ENGINE**

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[63] Continuation-in-part of Ser. No. 55,919, July 17, 1970, abandoned.

[52] **U.S. Cl.**..... **123/119 E,** 123/32 EA, 123/52 M, 123/119 R, 123/119 A, 123/191 B, 123/191 M, 60/39.74

[51] **Int. Cl. F02m 27/08,** F02m 29/00, F02m 27/00

[58] **Field of Search**..... 123/119 R, 119 E, 119 A, 123/198 E, 198 R, 52 M, 32 EA, 191 M, 191 B, 141, 1; 60/39.74, 275; 116/137, 137 A; 137/604; 239/4, 102; 261/DIG. 48

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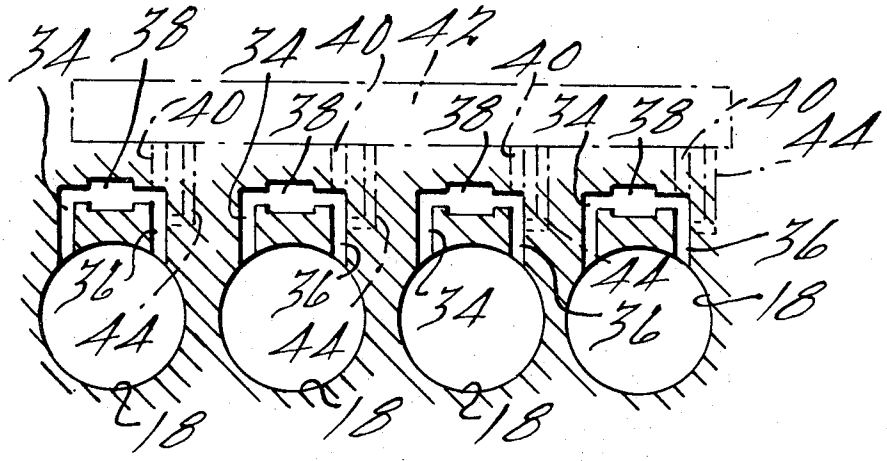
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[57] **ABSTRACT**

A high efficiency, low pollution engine utilizing a source of ultrasonic energy to produce atomization of the fuel or fuel mixture preparatory to or after the fuel has been delivered to the combustion chambers of the engine; the means for producing the ultrasonic energy including in part the high pressure gases or gaseous mixture produced by the engine itself during operation thereof. The high pressure gases are caused to pass over or through a suitable whistle like structure that produces high frequency or ultrasonic sound wave energy which is selectively communicated to the fuel prior to the same being ignited within the engine's combustion chambers and/or to the engine exhaust.

9 Claims, 4 Drawing Figures



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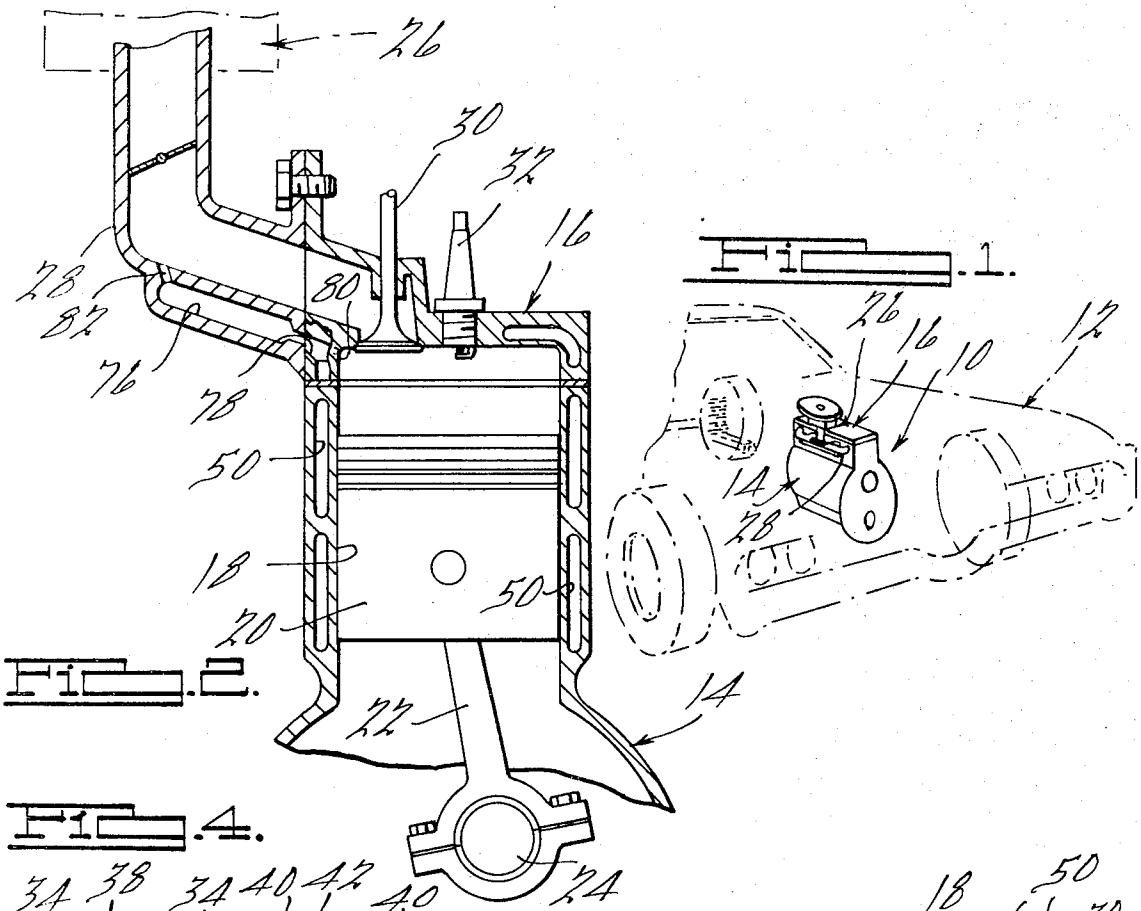


Fig. 2.

Fig. 1.

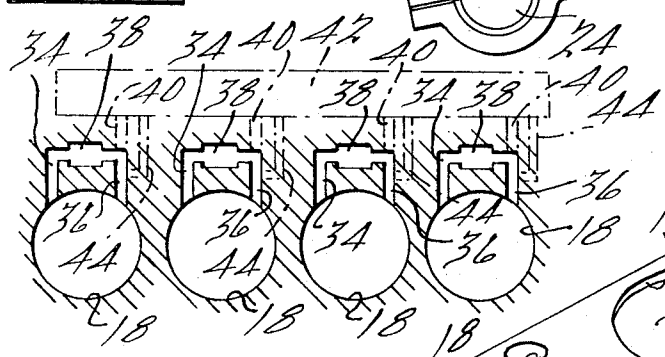


Fig. 4.

Fig. 3.

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HIGH EFFICIENCY-LOW POLLUTION EMISSION ENGINE

CROSS REFERENCE TO PRIOR APPLICATION

This application is a continuation-in-part of U.S. application Ser. No. 55,919, now abandoned filed July 17, 1970, for: High Efficiency-Low Pollution Emission Engine.

BACKGROUND OF THE INVENTION

In the early days of the automobile, it was favored with an ideal fuel which was capable of being completely volatilized in a simple, venturi-type carburetor to form a stable fuel-air dispersion or engine charge and low emission levels. More recently, however, in response to demands for improved convenience and performance, petroleum fuels consist of an assortment of distillation fractions or cuts which vary widely in their capacity to vaporize in the throat of a venturi-carburetor under the wide range of temperatures, pressures and velocities which exist under various speeds and load conditions of the associated engine. As a result, an unstable engine charge may be formed which readily coalesces into a liquid in the engine manifold. This liquid fuel is drawn into the combustion chamber where it causes fouling of the spark plugs and crankcase oil dilution. This, of course, results in low efficiency operation of the engine and the consequential emission of unburned hydrocarbons and carbon monoxide pollutants into the atmosphere. Present day volatility fuels also interfere with rapid acceleration from low speed to high speed due to the insufficient vaporization of the fuel in the venturi when the velocity of the air flowing therethrough is of a relatively low magnitude. To overcome these conditions, present day carburetors are commonly provided with supplementary pumps or injectors which supply additional fuel for acceleration. With these devices, however, a great deal of raw fuel is introduced into the combustion chambers of the engine with the resultant loss in efficiency and the even greater emission of unburned hydrocarbons and carbon monoxide into the atmosphere.

It is heretofore been discovered that the combustion efficiency of an engine can be substantially improved, thus effecting a substantial reduction in the emission of pollutants into the atmosphere, by reducing the size of the droplets of fuel in the air-fuel mixture, such as is accomplished when the fuel is atomized. It has been discovered that one highly preferred way of achieving fuel atomization is to subject the air-fuel mixture to a source of ultrasonic energy, either prior to this mixture being introduced into the combustion chambers of the engine, or subsequent thereto. As an ultrasonic wave front passes by and through a fuel droplet, the droplet first experiences a high level of compression, followed by a high level vacuum. The mechanical motion induced by the compression enhances the "boiling" which is a result of the vacuum phase. The result is very rapid atomization. A wide variety of different types of ultrasonic sound generating devices have heretofore been proposed and used, a number of which devices are shown in U.S. Patents, Nos. 2,791,990; 2,732,835; 2,949,900; 2,908,443; 2,454,900; 2,532,554; and 2,791,994. However, all of the devices disclosed in the aforementioned patents and other devices known in the prior art utilizing a source of ultrasonic sound energy

for effecting atomization of fuel, have been objectionable from the standpoint that they require a substantial amount of ancillary equipment, such as sound generating devices, diaphragms, electronic devices, etc. in order to produce a source of ultrasonic energy. Accordingly, such prior known devices have been highly objectionable due to the added expense required and the amount of space required for such ancillary equipment, particularly where space is at a premium such as in the engine compartment of a modern automotive vehicle which is intended to house not only the vehicle engine but virtually all of the engine accessories such as the air conditioning, heating, hydraulic and pneumatic power devices and the like.

The present invention is intended to overcome the aforementioned objectionable problems through the provision of a new and improved method and apparatus for producing high frequency sound energy which is achieved by ultrasonically exciting or vibrating the high pressure gas or gaseous mixture that normally exists during operation of an internal combustion engine. When the fuel/air charge is ignited, the expansion of the charge results in a high pressure condition within the ignition chamber. In the subject invention, a small volume of the high pressure gaseous product is allowed to escape from the chamber via a small port which acts as an acoustic whistle. The actual construction of the port and connecting passage area is designed to enhance the sound energy level and be a frequency selective structure.

With respect to the art and determining factors for the design of the port and passage area adjacent to the port area to produce high intensity sound waves, U.S. Pat. No. 2,800,100 of Raymond Marcel Guy Boucher entitled "Generator for Sonic and Ultrasonic Vibrations" can be perused for specific improvements in the design of acoustic whistles. Moreover, acoustic whistles are commercially available which represent considerable sophistication when compared to an ultrasonic dog whistle, factory whistle, or railroad steam whistle. Additional information concerning designs of these devices and excitation structures referred to in this disclosure are contained in various publications devoted to the uses of ultrasonic energy such as, for example, a periodical entitled "Ultrasonic News." This high pressure gas or gaseous mixture is caused to pass over or through a structure that causes the mixture to vibrate at a high frequency, after which the ultrasonically excited mixture, or the ultrasonic energy so generated is transmitted directly into the combustion chambers and/or various fuel and exhaust passage areas of the engine to effect atomization of the fuel or air-fuel mixture therein. Also, the ultrasonically excited gas mixture or ultrasonic energy produced from the excited gas mixture may be transmitted to some location where it may act upon the air-fuel mixture as said mixture is being transmitted to the combustion chambers. It is contemplated that a resonant chamber or chambers may be provided to sustain desirable sound wave frequencies and help maintain stability and longevity of the desired frequencies as the high pressure gaseous material is communicated from its source, i.e., from the combustion chambers or areas of the engine, to the location where it is impinged or directed against the air-fuel mixture, or to sustain the ultrasonic energy being conducted by the metal of the engine to specific areas to act on the fuel mixture, or other energy transmitted

medium that will conduct the ultrasonic energy to areas where the presence of the energy is desired.

In accordance with the present invention, a system of passages or flow paths are provided within the engine, which passages are arranged so as to receive the pressurized gases or gaseous mixture produced during operation of the engine and to communicate these high pressure gases, first to the structure for ultrasonically exciting the same, and then back to the cylinder areas. The introduction of the high frequency energy into the combustion chambers is designed so as to provide for maximum "washing" of the cylinder areas, with such washing causing a highly effective mixing of the air-fuel molecules within the combustion chambers, as well as a breaking up of the fuel droplets into smaller droplets, resulting in the promotion of complete combustion of the air-fuel mixture when the air-fuel charge is ignited. It may be noted that the transmission of the high frequency energy into the cylinders not only promotes efficient combustion thereof, as above described, but also discourages the collection of carbon particles and foreign materials on the surfaces within the combustion chambers and fuel mixture passages, thereby minimizing the accumulation of any such material which ordinarily tends to inhibit complete burning or combustion of the successive air-fuel charges transmitted into the cylinders. Alternatively, an energy transferring medium other than the excited high pressure gaseous mixture may be employed in place of the gas mixture which is used to generate the ultrasonic energy. This medium may be solid, liquid or gaseous material.

SUMMARY OF THE INVENTION

This invention relates generally to a new and improved method and apparatus for operating internal combustion engines by using high frequency sound vibration or energy, particularly ultrasonic vibrations, to produce a more complete atomization of the air-fuel mixture. More particularly, the present invention relates to a new and improved internal combustion engine wherein the source of ultrasonic energy is provided by the high pressure gases or gas mixture produced during operation of the engine.

It is accordingly a general object of the present invention to provide an internal combustion engine which utilizes a new and improved arrangement for producing ultrasonic energy for effecting atomization of the air-fuel mixture, or other fuel mixture.

It is a related object of the present invention to provide a new and improved internal combustion engine of the above character which utilizes ultrasonic energy for atomizing the air-fuel mixture without the use of any ancillary sound generating devices.

It is a more particular object of the present invention to provide a new and improved internal combustion engine of the above character which utilizes pressurized gas or a gas mixture produced during operation of the engine as a means for producing the ultrasonic energy.

It is a further object of the present invention to provide a new and improved internal combustion engine of the above described type wherein the gaseous mixture utilized in producing the ultrasonic energy is communicated to the engine cylinders by means of flow paths which are formed directly within the engine block and/or cylinder head. If the space required for these passages is not conveniently available, it is anticipated that portions of the passages required may be provided by pipes or tubing which connect the cylinders, manifold and fuel passage areas.

It is still another object of the present invention to provide a new and improved internal combustion engine of the above described type wherein the ultrasonic energy may be transmitted directly to the combustion chambers thereof of preparatory to ignition of the air-fuel mixture, or alternatively, may be transmitted to the carburetor or to the intake manifold communicating the air-fuel mixture between the carburetor and the engine cylinders, or communicated to structures which inject the fuel into the cylinders.

It is another object of the present invention to provide a new and improved engine wherein the gaseous mixture utilized in producing the ultrasonic energy communicates the energy to a different material or medium which then communicates the ultrasonic energy to areas of the engine where it can be beneficially used.

A further object of the present invention is to provide a source of ultrasonic energy which will better atomize fuel from fuel injectors and prevent clogging or contamination of the fuel passages and control devices by the selective application of such energy.

It is another object of the present invention to provide a new and improved internal combustion engine which utilizes ultrasonic energy that provides for improved power output of the engine and optimum acceleration response during all operational conditions thereof.

It is still a further object of the present invention to provide a new and improved ultrasonic air-fuel atomizing arrangement which will find particular application in conventional and internal combustion engines, but which may also be utilized in gas turbines and other prime movers.

It is also an object of the present invention to provide an efficient means of limiting the accumulation of various deposits in the combustion chambers, carburetor, manifold, or fuel injecting structures of the engine as a result of the ultrasonic energy generated being conducted to or impinged upon areas where these deposits may degrade the optimum performance characteristics of the engine.

Other objects and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevated perspective view of an internal combustion engine in accordance with the present invention, as shown in typical operative association with a schematically illustrated automotive vehicle;

FIG. 2 is an enlarged transverse cross-sectional view of the internal combustion engine illustrated in FIG. 1, and illustrates one of the cylinders thereof in operative association with the ultrasonic energy producing concepts of the present invention;

FIG. 3 is an elevated perspective view, partially broken away, of a portion of an engine cylinder block, and illustrates certain features of the present invention; and

FIG. 4 is a schematic illustration of a portion of an internal combustion engine in accordance with the principles of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

For purposes of description, the terms "fuel" and/or "air-fuel mixture", as used herein, are intended to encompass all types of combustible fuels, including fuels which are in a completely gaseous or liquid state, and fuels which have been combined in any way with atmospheric air or some other type of oxidizing media, and including energy producing systems commonly referred to as "fuel cells".

Referring now in detail to the drawing and in particular to FIG. **1,** an internal combustion engine **10,** in accordance with one embodiment of the present invention, is shown in operative association with a typical automotive vehicle **12.** The engine **10** is shown as comprising an engine block **14** and a cylinder head **16** which cooperates to define a plurality of cylinders **18** within which a plurality of reciprocal pistons **20** are disposed. The pistons **20** are connected via suitable piston rods **22** to a crankshaft **24** in a conventional manner. The engine **10** is provided with a conventional carburetor **26** which is communicable with the plurality of cylinders **18** via an intake manifold **28** and a plurality of conventional intake valve openings **30.** Additionally, the engine **10** is provided with conventional exhaust valve openings **31** that are communicable with a standard exhaust system (not shown). Each of the cylinders **18** is provided with a suitable ignition or spark plug **32** which is adapted to function in a conventional manner in effecting ignition of successive charges of the air-fuel mixture which is communicated to the cylinders **18** from the carburetor **26** via the intake manifold **28.**

In accordance with the present invention, the engine **10** is adapted to be provided with means for effecting atomization of the air-fuel mixture communicated from the carburetor **26** to the plurality of cylinders **18** in order to provide for efficient, pollution free combustion. The particular means for effecting atomization of the air-fuel mixture comprises a source of ultrasonically excited or energized gas which is adapted to be impinged or directed upon the air-fuel mixture preparatory to combustion thereof within the cylinders **18.** With more particularity, the present invention is directed toward a novel means for utilizing pressurized gas or gas mixtures which are produced during operation of the engine **10** as a source of the aforesaid ultrasonic energy, whereby the engine **10** may operate independently of any ancillary ultrasonic energy generating devices such as have been utilized in the prior art. As will hereinafter be described in detail, the ultrasonic energy for effecting atomization of the air-fuel mixture is produced by communicating pressurized gas or gaseous mixtures from the plurality of cylinders **18** via suitable flow paths within the engine **10** to a suitable ultrasonic energy generating structure preferably located directly within the engine, the ultrasonic generating structure acting in the manner of an acoustic whistle designed to operate when a suitable pressure differential exists across the ultrasonic generating structure. These gases or mixtures are then ultrasonically excited within the structure and are then directed back into the plurality of cylinders **18** where they act upon the air-fuel mixture communicated thereto from the carburetor **26** to effect atomization of said mixture preparatory to ignition and combustion of the mixture within the cylinders **18.**

Referring now to FIG. **4,** for example, in accordance with the present invention, each of the cylinders **18** is adapted to be communicable via a pair of outlet and inlet flow passages **34** and **36,** respectively, with an ultrasonic energy producing structure, generally designated **38,** which is adapted to produce ultrasonic energy in response to receiving pressurized gases produced during the power stroke in each of the cylinders **18.** The particular structure for producing the ultrasonic energy may be of any suitable design well known in the art, and may, for example, consist of a resonator chamber, the particular dimensions and volumes of which are designed such that the pressurized gases passing therethrough will be ultrasonically excited or energized. The excited gases are then communicated through the flow passages **36** back into the cylinders **18** to act upon the air-fuel mixture delivered thereto via the intake manifold **28.** By properly designing the interior of the various structures or chambers **38,** a "broad band" frequency response is possible that will accommodate the density variations that are encountered at various speeds and degrees of loading the engine **10.** While it will be readily apparent to those skilled in the art that ultrasonic energy may be produced solely by passing the gaseous mixture produced within the cylinders **18** through a suitable cavity of the preselected dimensions or across various structures within the passages, it is to be noted that in order to supplement the energy producing action of the structures **34, 36** and **38,** the engine may be provided with certain ancillary ultrasonic sound generating devices, such as are well known in the prior art and are shown, for example, in U.S. Pat. Nos. 2,532,554; 2,791,994; 2,791,990 and 2,732,835.

For certain applications, it may be desirable to provide or supplement the ultrasonic structures **38** with a reservoir or accumulator which functions to receive and store ultrasonically excited high pressure gas that is to be returned into the cylinders **18** to effect atomization of subsequent air-fuel charges delivered thereto. By way of illustration, the outlet portions of the ultrasonic structures **38** may be communicable via suitable passages **40** with an ultrasonic energy accumulator **42,** as shown in FIG. **4,** with the accumulator **42** being communicable via the inlet passages **36** of each of the cylinders **18** through suitable passages **44.** The particular construction of the accumulator **42** is preferably designed so as to provide for a more constant dispensing of such energy into the passages **44, 36** to the cylinders **18,** with the particular construction and design of the accumulator **42** being apparent to those skilled in the art so that a detailed description thereof is omitted for purposes of simplicity of the disclosure. It may be noted, however, that the accumulator **42** may house a single or common ultrasonic gas exciting or generating structure which is communicable with each of the cylinders **18,** so as to obviate the need for separate structures **38** for each of the cylinders **18.** In accordance with the present invention, it is contemplated that the various passages communicating the cylinders **18** with their associated ultrasonic producing structures, as well as the structures themselves, may be formed directly within the engine block, engine head and/or head gasket. For example, with reference to FIG. **3,** it will be seen that the engine, together with being formed with the cylinders **18,** is provided with conventional exhaust and intake passages **46** and **48,** respectively, communi-

cable with the valve openings **30, 31.** Additionally, suitable cooling water flow passages **50** are provided. It is contemplated that during the casting or molding of the engine, for example, suitable cylinder ports which may also be designed to act as ultrasonic generating structures, generally designated **52,** may be simultaneously cast and arranged so as to be communicable with the cylinders **18.** The pairs of cylinder ports **52** communicating with the cylinders **18** may be in turn communicable with suitable flow paths **54, 56** and **58, 60,** which flow paths are communicable via cross passages **62** and **64,** respectively. The cross paths **62, 64** are in turn communicable with converging intersecting paths **66** and **68** that are communicable via suitable conduit means **70** and **72** with an energy accumulator or reservoir **74.** It is contemplated that not only the cylinder ports **52,** flow paths **54–60** and passages **62–68** may be cast directly into the engine block **14,** but also, the particular ultrasonic energy producing structure associated with the cylinders **18** may be cast directly therein. For example, such ultrasonic energy producing structures may be located directly within the cross paths **62, 64** and in an alternate arrangement, such ultrasonic structures may be combined with the accumulator **74** which may or may not be disposed interiorly of the engine block **14,** depending upon the particular design of the engine **10.**

Yet another alternate arrangement for selectively communicating each of the cylinders **18** with a structure for ultrasonically exciting the engine produced high pressure gases is shown in FIG. **2,** wherein an ultrasonic energy generating structure or chamber **76** is shown in a unitized relationship with respect to the intake manifold **28** of the engine **10.** The structure **76** may be common to all of the cylinders **18,** or a separate structure **76** may be provided for each of the cylinders **18,** as is schematically shown in FIG. **4.** In either type of arrangement, the structure **76** is communicable via a suitable flow passage **78** and cylinder port **80** with the cylinder(s) **18,** whereby pressurized gas or gaseous mixtures may be communicated from the cylinder **18** to the structures **76,** whereby such gases, by virtue of the particular design of the structure **76,** are ultrasonically energized and are then transmitted back into the cylinders **18** to effect atomization of the air-fuel mixture subsequently delivered thereto. It is contemplated that some of the ultrasonic energy produced within the structure **76** may be communicated via a suitable flow passage **82** directly into the intake manifold **28** for effecting "pre-mixing" and "pre-atomizing" of the air-fuel mixture preparatory to said mixture being delivered into the cylinders **18,** thereby further promoting efficient and pollution-free combustion.

In regard to the form and construction of the various ports, passages, resonance structure, and reservoir or accumulators, an exemplary embodiment in accordance with the subject invention will now be described. Considering first the ultrasonic generating structures and with reference to FIGS. **1–4,** the structures may be formed as convergent-divergent orifices. The orifices can be designed so that a flow rate through the restricted area is supersonic with a 60 p.s.i. differential across the restriction. The cylinder ports **52** and **60** can be constructed in accordance with a classical Hartmann ultrasonic whistle, i.e. the diameter of a resonance cup being approximately twice the restricted port diameter. In this regard, and by way of example, a restricted port diameter of 0.1 inch is selected. In accordance therewith a separate resonance cup will be provided having a 0.2 inch inside diameter passage. A sharp corner chamfered opening approximately 0.1 inches deep is positioned coaxially with the passage and spaced 0.1 inches from the cylinder port **52.** In accordance with the above, the cylinder ports **52** or **80** will be found to generate ultrasonic oscillations in the 25,000 to 50,000 Hertz range with normal pressures developed in the cylinders **18** during the initial cranking of the engine **10.** To augment the power output of ultrasonic energy, two ports **52** per cylinder can be used. For a more precise description relative to the above, reference may be had to Hartmann, Jul. and Trudso, E., "Synchronization of Air-Jet Generators —etc." *Danish Mat. Fys. Medd.* (Copenhagen), 1951.)

In regard to the resonance structures, to preclude the generation of reenforcement of audible range oscillations, various resonance constructions can be utilized. The passages **54, 56, 58, 60** as illustrated in FIG. **3,** are shown with a portion of the passage extending past the ports **52.** This extension effectively sets a limit on wave lengths which are compatible to the system resonance. By using 0.2 inches (or less for higher wave length spectrum) ultrasonic frequencies are readily reinforced for resonance while audible spurious frequencies which will occur will not be reenforced due to their longer wave lengths. Convenience precludes location of ports **52** with a separation spacing consistent with the limiting wave length distances whereby limiting may again be accomplished by offsetting the passages **54** in a stair step fashion along their communicating length. These offsets will breakup lower frequency resonances and also provide suitable intersection points for passages **66** and **70** of FIG. **3.** The passages **62, 64, 34, 36,** as will be appreciated, require a slightly different approach. Due to the engine firing order, the communicating passages **62, 64** must not allow pre-ignition of a cylinder on a compression stroke by an adjacent cylinder that may be on its power ignited stroke. The power stroke contains pressure far in excess of the pressure required to produce supersonic velocity through the port generator structures **52.** Since it is well known that the mass transfer through a supersonic orifice does not increase linearly with pressure increase, the high pressures generated by the exploding fuel-air charge do not over charge the passage system. The pressure drop across the system also acts to effectively reduce the ignition pressure flow rate through the ports **52.** For this reason the passages **62** and **64** should feed adjacent cylinder passages **56, 58** at or near one of the staircase offsets and away from ports **52.** With reference to the passages throughout the communicating network, the passages are constructed so as to provide a sufficiently large pressure drop whereby to act as a control on total system pressure. In this regard a diameter of 0.1 to 0.2 inches will act as a control on the operating pressures maintained in the pressure reservoirs **42, 74** and **76.**

With reference now to the reservoirs, it will be noted that the reservoirs function as an intermediary between the input ultrasonically excited pressure and a more controlled ultrasonically excited energy and directs the energy to areas where the ultrasonic agitation of the fuel-air charge can be most beneficial. The reservoirs **42, 74** and **76** can be located, for example, in the intake

manifold casting between adjacent intake passages of the manifold.

Two preferred methods of exciting the incoming fuel-air charge can be employed. The first method relates to surface excitation of the inner wall of the manifold passages. This is accomplished by constructing the reservoir such that the interior space is shaped to present a series of cylindrical chambers communicated by a passage running at substantially a right angle to the axis of each of the cylindrical chamber resonators. The end walls of each of the cylindrical chambers can be common with the interior walls of the intake manifold passages. In this construction, the resonance chambers act also as a pressure reservoir, to receive ultrasonically excited pressurized gases from the passages **70** and **72** or from exciting ports **80, 78.** The chambers can be approximately 0.2 inches in diameter and approximately 0.4 inches long and the wall of each chamber which communicates with the next chamber includes an aperture or passage approximately 0.1 inches in diameter. The axis of the series of communicating holes are at right angles to the resonant chambers. As the input pressurized excited gas flows into the structure **76,** ultrasonic energy will be expended into the walls of the intake manifold passages.

A second method pertains to the direct excitation of the incoming fuel charge. In accordance with the second method, a Hartmann generator, of the type previously described, is disposed at the communicating port **82.** The pressure volume transition that occurs where port **82** exits into the interior of the intake manifold is somewhat analogous to the function of the extensions of passages **54, 56, 58,** and **60.** The length of port **82** would be somewhat longer to accommodate the different boundary conditions of an "open ended" tube. Since the flow from the port **82** to the intake manifold must be held within a preselected maximum, in accordance with the effect on manifold vacuum, this passage has a relatively small outlet diameter (0.05 approximately). Correspondingly, the outlet passages **40, 44, 70, 72** are connected so as to relieve the output flow from the Hartmann generator. In this manner, only a minimal mass flow through port **82** will be experienced. With respect to the cylinder inlet ports, it has been found that the existence of ultrasonic wave fronts on one side of any of the ports **34, 36, 52, 80** and **82** correspondingly excites a similar response on the other side. However, the exciting structures are non-reciprocal. For this reason the ports **34** and **36** (again approximately 0.1 inches in diameter) are supplied by the more or less stabilized reservoir pressure through Hartmann generators. The generators are located where passages **40** and **44** communicate the passages **34** and **36.** The structure **38** is a resonant cavity or alternatively a series of end communicated resonant cavities of approximately 0.2 inches in diameter and 0.4 inches in length in communication with the passages **34** and **36.** Thus, it will be seen that the interior engine cylinder area is a portion of an ultrasonic resonant structure wherein pressure and ultrasonic wave energy is directed through other ultrasonic wave energy generating structures directly to the cylinder **18.**

The complete system of passages, reservoirs, resonators, and generators is thus contained within the engine **10.** Relatively small quantities of the intake to the engine are transferred through the ultrasonic system and returned to various areas of the engine wherein the ultrasonic energy produced will be most beneficial to the operation of the engine.

A very simplified version in accordance with the principles of the subject invention may be structured from a basic Hartmann generator arrangement. Note that a passage of approximately 0.6 inches in diameter can be provided in the wall of the intake manifold **28** immediately under the carburetor **26** and can be adapted to receive an ultrasonic energy generating and resonating device. This device can be supplied with pressurized air from an air pressure pump that normally supplies cooling air to the exhaust gases on many of the current engines. The ultrasonic energy generating and resonating device can be constructed, for example, in the manner of a "multi-whistle." In this regard, reference can be had to U.S. Pat. No. 2,800,100 of R. M. G. Boucher, that patent being incorporated herein by reference. In the multi-whistle, a plurality of Hartmann type generators are disposed around a circle. A plurality of secondary resonance chambers are provided and the ultrasonic wave output is tuned to the outlet boundary conditions by means of an exponential horn structure. The output end of this matching structure would be covered by the end of a cylindrically shaped container that totally encloses the multi-whistle. Moreover, the container can include an air pressure inlet to the whistle, an annular plenum chamber therearound, and can be attached to the lines that carry off the expended air therefrom. In this regard, it will be noted that the expended air is still pressurized, but at a relatively lower pressure, and can be directed to the exhaust manifold. The multi-whistle output end of the cylindrical structure that contains the whistle is constructed so as to act as a membrane or diaphragm which is excited into ultrasonic vibrations by the ultrasonic waves generated by the whistle. As will be noted, the membrane or diaphragm can be disposed in the interior of the 0.6 inch diameter hole provided in the intake manifold **28** whereby to form a portion of the interior wall thereof. Moreover, it will be noted, that in the absence of an air pressure pump, the whistle can be supplied with pressure from the interior of the engine **10** via a structure similar to that illustrated in FIG **2,** by replacing the reservoir **76** by the multi-whistle. Also, the exhaust from the whistle which contains the high ultrasonic energy can be directed into the carburetor **26** inlet. This would provide a further source of ultrasonic energy to the fuel-air charge and would have the advantage of burning the unburned fuel from the compression stroke of the engine **10** to enable the ultrasonic system to recover the power lost from the fuel that previously entered the system.

In operation of the internal combustion energy engine **10** embodying the principles of the present invention, high pressure gases will be produced in each of the cylinders **18** during the successive power strokes thereof. These gases are conducted through the appropriate energy ports and passages to the associated ultrasonic energy generating structure, and if desired, to the associated reservoir or accumulator which provides for a more constant dispensing of the ultrasonic energy back into the cylinders. As the cylinders **18** undergo their respective intake strokes, the air-fuel mixture which is communicated thereto through the intake manifold **28** is impinged by the continuing flow of ultrasonically excited gases, whereby the air-fuel mixture is caused to vibrate rapidly, resulting in highly efficient

molecular mixing of the fuel and air, as well as breaking up of the fuel droplets into smaller or atomized droplets. This action will promote more efficient and complete combustion when the fuel-air mixture is ignited during the subsequent power stroke. Additionally, the air-fuel mixture, when subjected to the ultrasonic excited gases, will be sufficiently stimulated and thereby heated to some degree due to the molecular movement of the mixture, which even further promotes efficient pollution-free combustion. It may be noted that the volume of ultrasonically excited gases introduced into the combustion chambers will be of such a low magnitude so as to not upset the normal flow of air and fuel charges into the cylinders **18** during their respective intake strokes. As the respective cylinders **18** undergo their combustion or power strokes, the interior of the cylinders **18** will be subjected to the ultrasonic excited gases which will discourage collection or accumulation of carbon particles on the interior surfaces thereof, which will assist in the cleaning of foreign unburned material within the cylinders **18** that would ordinarily tend to inhibit complete combustion of the next charge of air-fuel mixture. Also, the high ultrasonic energy density that is produced by the small volume of high pressure gases that is channeled away from the cylinders during their power strokes will assist in cleaning all structures which connect with the cylinder areas.

It will be seen from the above description that the present invention provides a novel internal combustion engine design which is adapted to operate in an extremely and efficient and pollution-free manner. Through the provisions of the present invention, an extremely small portion of the power and energy available during operation of the engine is diverted to the associated ultrasonic structure, and this small amount of energy will serve to produce copious quantities of ultrasonic excited gases which are subsequently returned to the engine cylinders to effect atomization of the air-fuel charges and hence promote the aforesaid highly efficient operation of the engine. It may be noted that if the particular engine is provided with a compressor that acts upon input air, such as a turbine type engine, for example, highly pressurized air from one of the final compressor stages may be used as a source of pressurized gas that may be ultrasonically excited and then communicated to the associated combustion area. Further, it is contemplated that the principles of the present invention may be utilized in connection with rotary piston type engines or with engines which feature fuel injection systems. With regard to such fuel injection systems, it is conceivable that the various passages and/or conduits described herein may be provided via suitable ducting directly within the fuel injection system, such as within the injector nozzles thereof. It will thus be seen that the present invention provides a highly efficient and pollution emission free engine without requiring the use of any ancillary generating mechanisms which have been traditionally objectionable due to their high costs and undesirable space requirements. Additionally, it will be noted that together with the various conduits, passages, etc. which may be utilized for conducting pressurized gases and ultrasonic energy within an internal combustion engine, as hereinabove described, it is conceivable that the metal structure itself of such engines may be used for conducting such ultrasonic energy to the various locations where it may act upon the air-fuel mixture to effect the atomization thereof. In this regard, it is contemplated that various types of metals or other materials may be utilized so as to optimize energy propagation within the engine structure. Further, while reference has been made herein to applying the ultrasonic energy produced by the pressurized gaseous mixture of an engine directly to the fuel or air-fuel mixture to be combusted therein, it may be noted that the present invention will also find particularly useful application in applying the aforesaid ultrasonic energy to the exhaust or by-products of the engine in order to effect a breaking down of the hydrocarbon and carbon monoxide molecules thereof, whereby to further reduce emission levels of the engine. Alternatively, such energy could be used to enhance the mixing of the exhausted by production of the engine with catalytic converting and hydrocarbon capturing agents known in the art. Thus, the principles of the present invention result in a substantial reduction in the emission of pollutants of an engine through both increasing the efficiency of combustion thereof and in reducing the hydrocarbon and carbon monoxide and noxious products exhausted therefrom.

While it will be apparent that the preferred embodiments illustrated herein are well calculated to fulfill the objects above stated, it will be appreciated that the present invention is susceptible to modification, variation and change without departing from the scope of the present invention.

I claim:

1. In an engine having at least one combustion chamber,

first means including a source of pressurized gas from said engine for producing ultrasonic energy, and

second means for subjecting the fuel mixture to said ultrasonic energy in order to atomize said mixture and thereby promoting efficient, pollution-free combustion said means including passage means formed directly in said engine for communicating said source of pressurized gas with said cylinder.

2. The invention as set forth in claim **1** which includes accumulator means for receiving and storing preselected quantities of said ultrasonic energy.

3. The invention as set forth in claim **1** wherein the engine comprises a plurality of combustion chambers and which includes integrally formed flow passage means located proximate and communicating each of said chambers with means for producing ultrasonic energy.

4. The invention as set forth in claim **3** which includes a separate means for producing ultrasonic energy for each of said combustion chambers.

5. The invention as set forth in claim **3** which includes a common means for producing ultrasonic energy for each of said combustion chambers.

6. The invention as set forth in claim **3** which includes accumulator means for containing preselected quantities of said ultrasonic energy and passage means communicating each of said combustion chambers with said accumulator means.

7. The invention as set forth in claim **1** wherein the engine comprises an intake manifold for introducing air-fuel charges into said combustion chamber, and wherein said means for producing ultrasonic energy is unitized with said intake manifold.

8. The invention as set forth in claim **7** wherein said passage means includes first flow path means commu-

nicating said combustion chamber with said means for producing said ultrasonic energy and second flow path means communicating said means for producing ultrasonic energy with said intake manifold.

9. The invention as set forth in claim **1** wherein said second means includes an ultrasonic energy producing structure, first flow path means communicating said combustion chamber with said structure in order to communicate pressurized gas from said chamber to said structure, and second flow path means communicating said structure with said combustion chamber in order to transmit ultrasonic energy from said structure to said chamber.

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