Nov. 12, 1963 B. C. G. NYMAN 3,110,294

METHODS AND APPARATUS FOR MIXING FLUIDS

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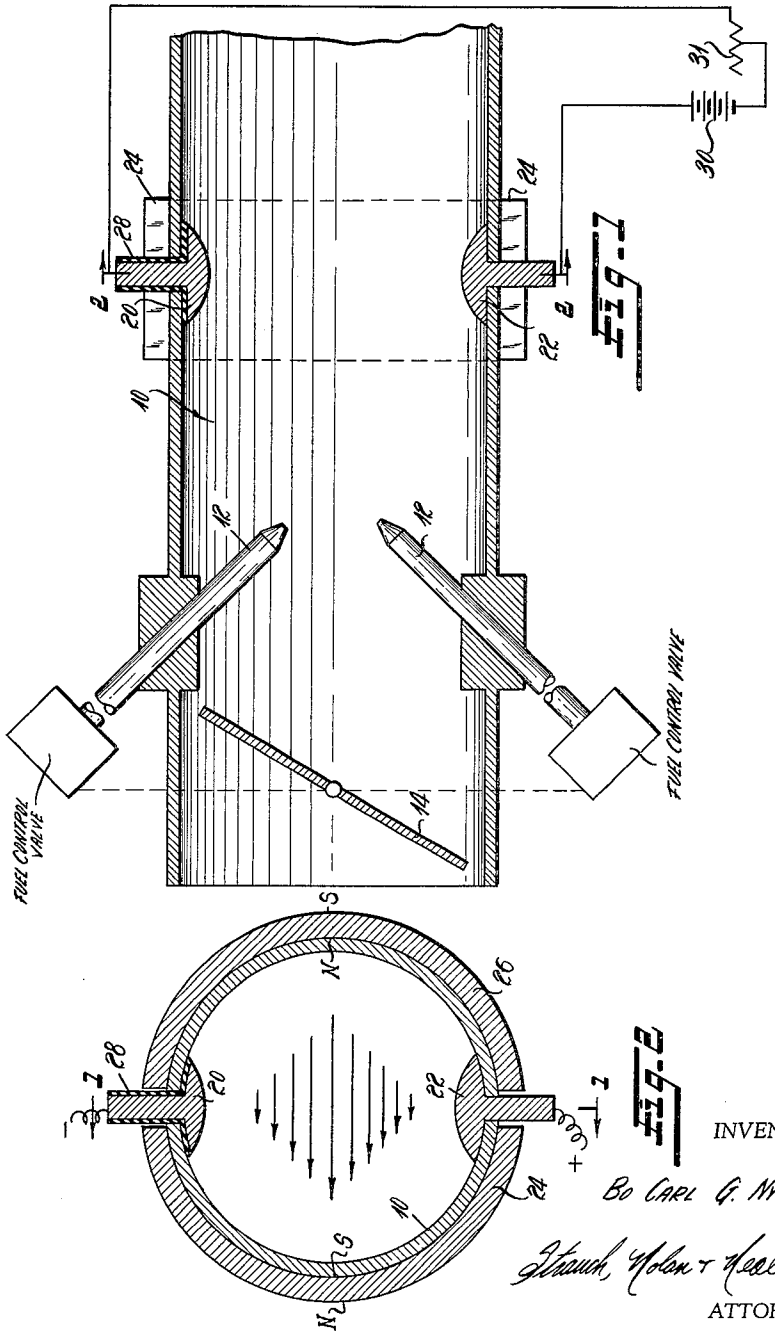


Fig. 1

Fig. 2

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METHODS AND APPARATUS FOR MIXING FLUIDS

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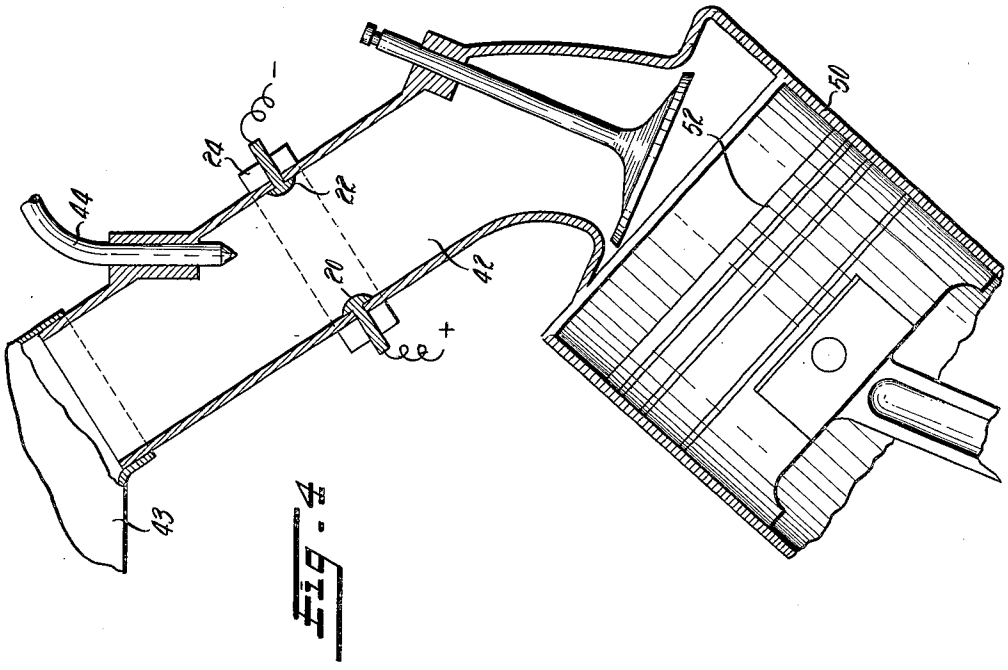


Fig. 4

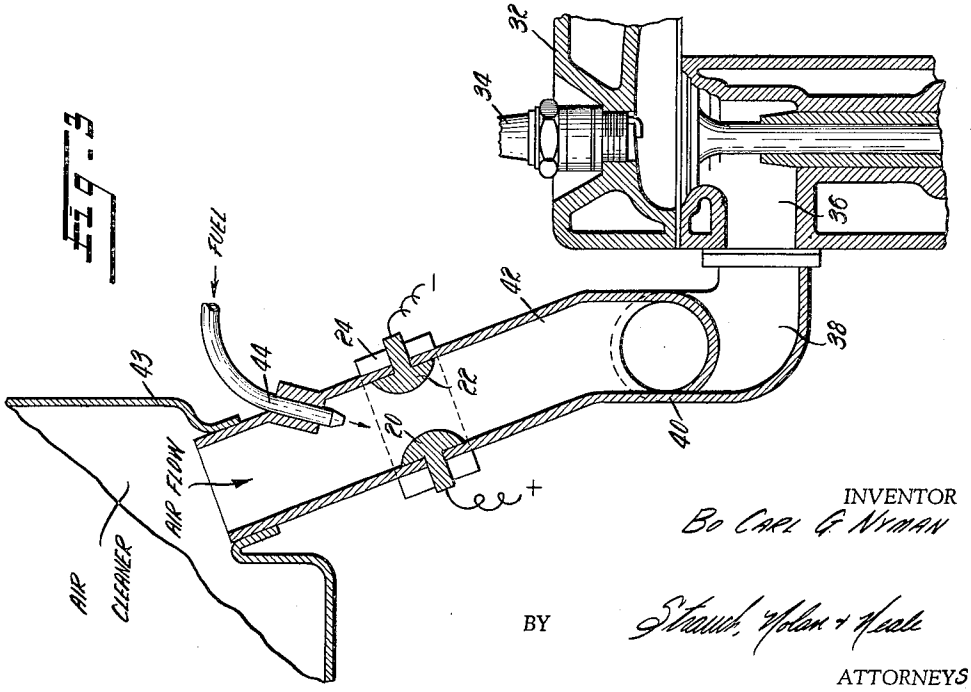


Fig. 3

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METHODS AND APPARATUS FOR MIXING FLUIDS

Filed Jan. 4, 1960 5 Sheets-Sheet 3

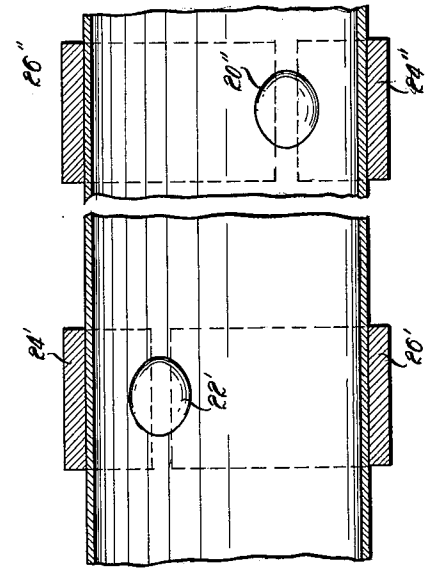
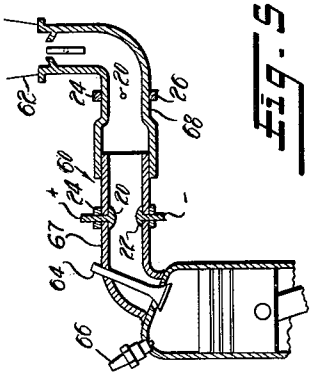


FIG. 5



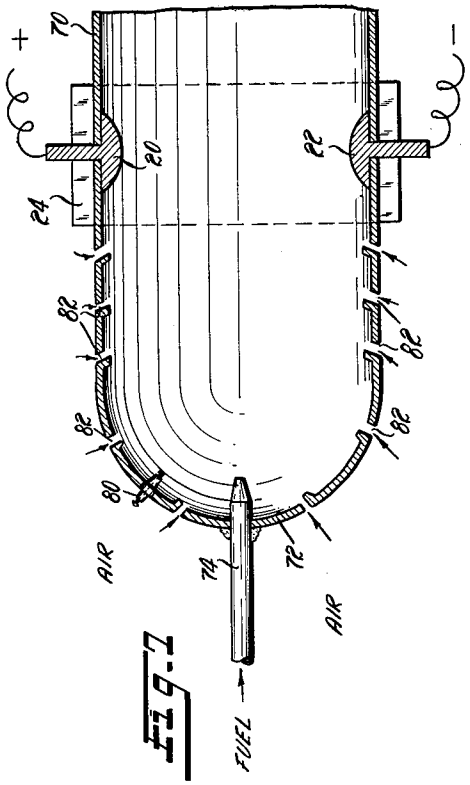


FIG. 7

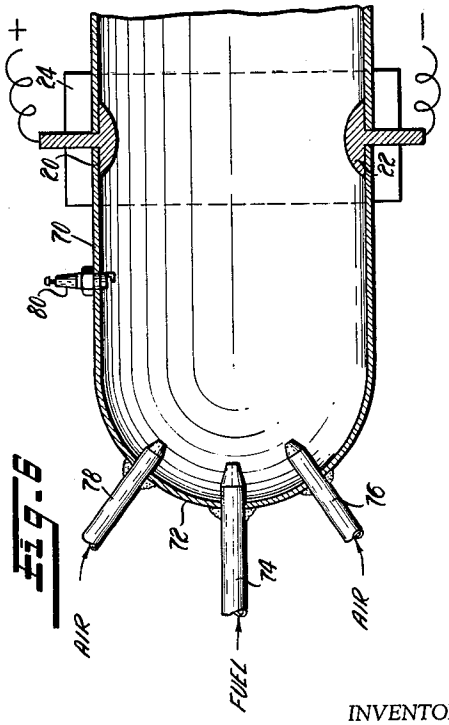


FIG. 6

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Nov. 12, 1963 B. C. G. NYMAN 3,110,294

METHODS AND APPARATUS FOR MIXING FLUIDS

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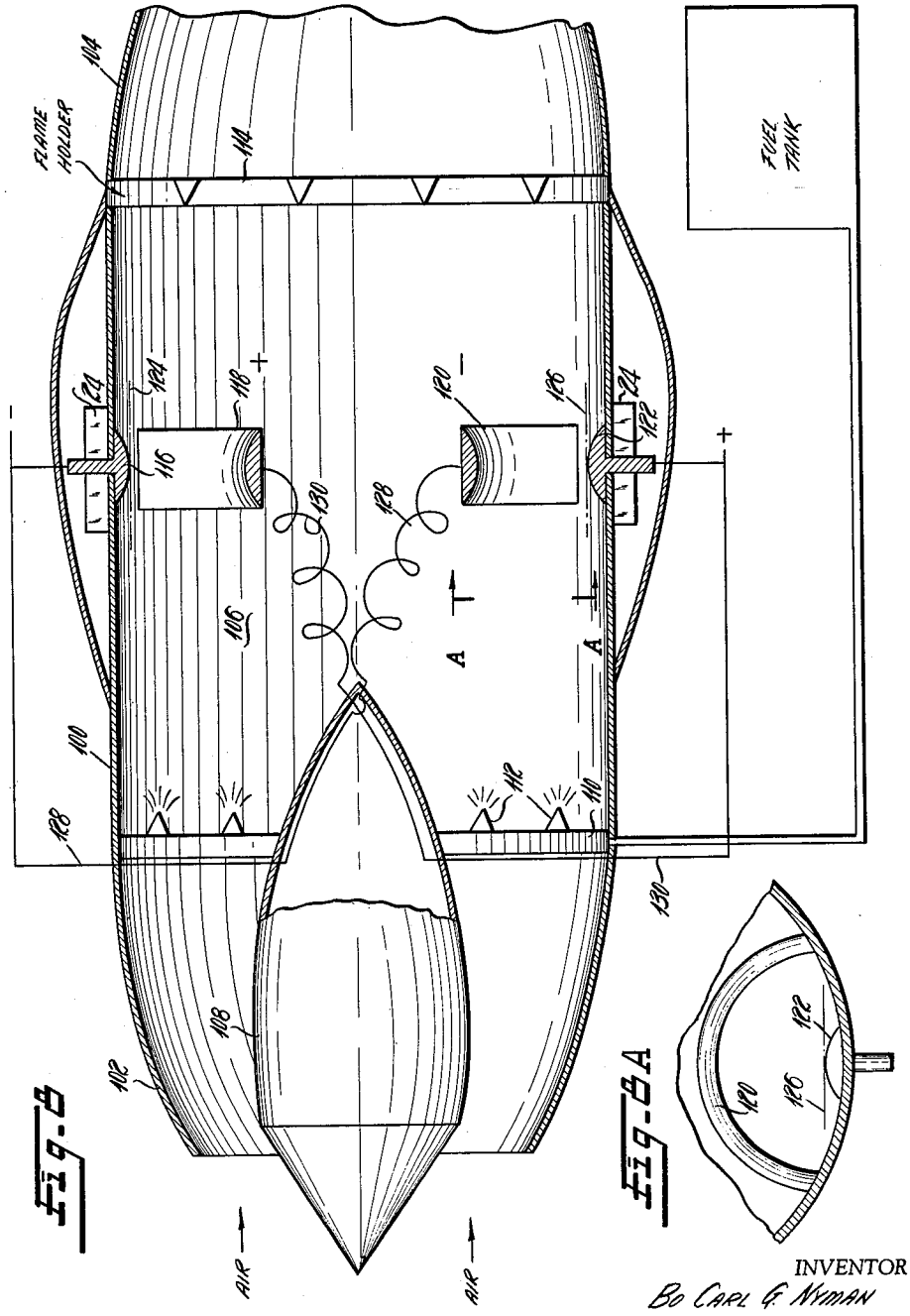


Fig. 3

Fig. 3A

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METHODS AND APPARATUS FOR MIXING FLUIDS

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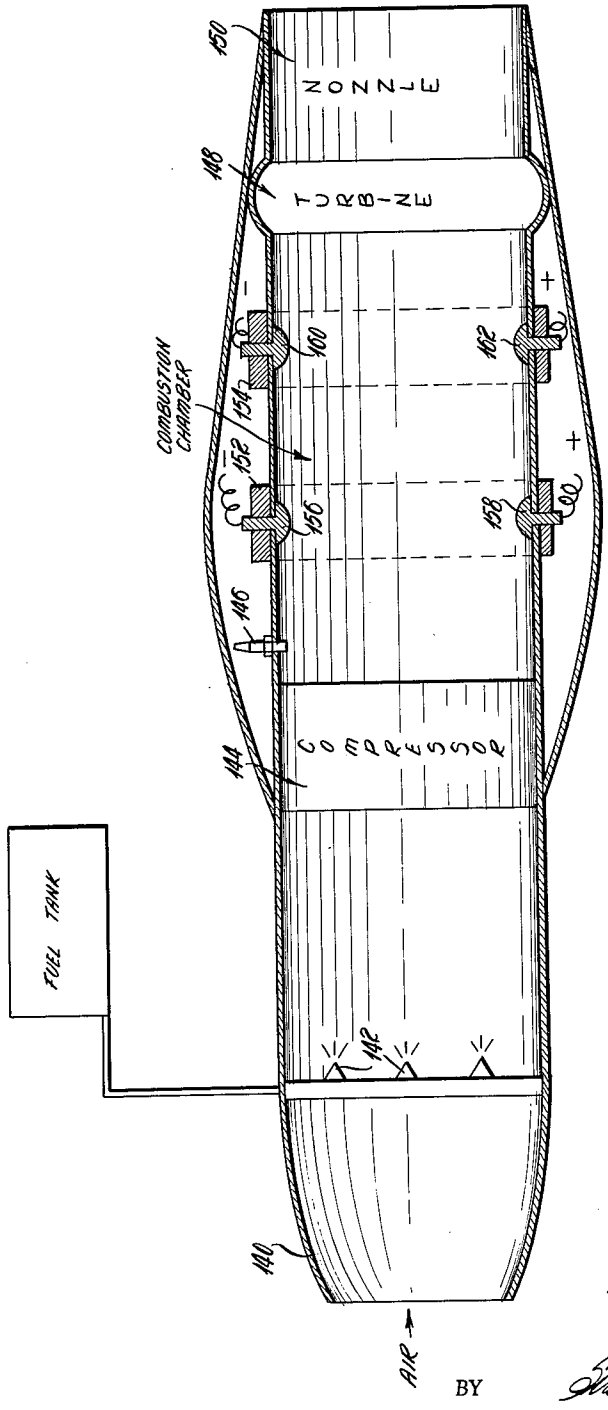


Fig. 6

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United States Patent Office 3,110,294 Patented Nov. 12, 1963

3,110,294
METHODS AND APPARATUS FOR MIXING FLUIDS

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Filed Jan. 4, 1960, Ser. No. 330
17 Claims. (Cl. 123—119)

This invention relates to method and apparatus for mixing fluids, and more particularly involves a mixing chamber that may be used in many mixing applications such as internal combustion engines of the reciprocating piston, gas turbine, turbojet and jet types, and in chemical processes, and for the generation of large volumes of gases for heating and generation of ionic winds and the like.

To obtain a thorough mixing of a first medium, e.g., combustive, but with a second medium, e.g., combustible, in a mixing chamber for eventual combustion, it is indispensable that some kind of turbulence be created in the fluid within the chamber. In known combustion chambers, turbulence in the fluid is conventionally created by one or more obstacles, either rigid or constituted by jets of an auxiliary fluid. These obstacles have the inherent disadvantage of creating zones where the fluid is not in proper circulation and thereby results in a loss of energy. The application of the present invention to combustion chambers, such as for example those used in internal combustion engines and as hereafter described is advantageous in that it aids in the proper mixing of the gases, the elimination of pulsations and noise and relatively clean combustion.

The improved results obtained by my present invention are attributable in large part to the ionization of gases and gaseous mixtures to increase their volume, the efficiency of reaction and hence their conversion into energy. I have discovered that the efficiency of fuel consumption and power produced for the development of energy is greatly improved by ionization which may result in dissociation of gaseous fuel mixtures under controlled conditions of temperature and pressure.

In general, my improved methods comprise a step of ionizing the air-fuel mixture, either prior to ignition or in the combustion chamber to thereby increase the volume of the products of combustion, their velocity away from the zone of ignition, and the efficency of mixing and combustion with the concomitant development of reduced pressures for the creation of a strong intake suction of the air-fuel mixture into the combustion zone after initiation of combustion. The resulting increase in efficiency of reactivity, energy release, gaseous thrust development, control and economy are marked, unexpected and surprising.

The benefits of my present invention can be realized to a substantial degree in many conventional types of internal combustion engines, oil burning combustion chambers and like by the addition of ionizing equipment at or in advance of the ignition zone to increase the volume and velocity of burning fuel mixture as well as the homogeneity of the air-fuel mixture. A further essential novel element of my present discovery is the utilization of a magnetic stabilizing field at the ionizing zone (the ionizing effect occurring at relatively low voltages) to control the ion flow pattern for maximum utilization.

Various prior efforts have been made to utilize ionization to increase reactivity of gases and vapors, but so far as I am aware, the prior efforts have not gone into substantial commercial use. In United States Patents No. 2,583,898 and 2,766,582 various proposals have been made where ionization is effected in the absence of magnetic fields and with ionizing potentials of at least 400

volts or higher. In the United States Patent No. 2,766,582, ionization of a dielectric type fuel prior to vaporization is disclosed. My invention differs from such prior efforts in ionizing the mixture to be reacted in the gaseous or vapor phase, by utilization of a magnetic field, with ionizing potentials preferably of the order of from about 6 to 120 volts, depending upon the size of the equipment used and the mixtures to be reacted, and in certain applications under high temperature and subatmospheric pressures. While higher voltages may be used, optimum results have been secured with mixtures so far reacted with relatively low voltages and little if any change is noted by the application of much higher voltages. While I am aware that magnetic fields have been utilized in the ionization and dissociation of gases in equipment such as Phillips vacuum and pressure meters, and in cyclotrons, I am not aware of any use of a magnetic field to increase reactive efficiency of gaseous mixtures.

The primary object of my invention is to provide novel methods and apparatus for the ionization and utilization of gases, gaseous mixtures, vapors and the like.

Another primary object of this invention is to provide novel methods and apparatus for the improvement of chemical reactivity of gaseous and vapor phase mixtures.

A further object of the present invention is the improvement of efficiencies and simplification of equipment for the development of heat energy and thrust from fuel in heat engines, internal combustion engines and fuel burners of well-known types and common use.

Still a further object of this invention is to provide method and means for ionizing the gaseous combustile mixture in the presence of the magnetic field either in a fuel mixing chamber prior to ignition of the mixture or in the combustion chamber.

Other detailed objects of my invention will be apparent from the foregoing general and the following detailed descriptions, from the claims, and from the appended drawings, wherein:

FIGURE 1 is a longitudinal view in section of a mixing chamber showing the ionizing electrodes and the means for producing a magnetic field, which chamber is adapted for replaceemnt of or use in conjunction with conventional carburetors of gasoline motors, spray nozzle equipment of diesel and solid injection type gasoline engines and supply of gaseous fuel mixtures to combustion chambers and oil, vapor and gas burners and the like;

FIGURE 2 is a cross sectional view of the mixing chamber of FIGURE 1;

FIGURE 3 is a longitudinal view in section of a portion of an L-head piston engine and intake manifold whereby the usual carburetor has been replaced by the present invention;

FIGURE 4 is a similar illustration of an overhead valve type piston engine;

FIGURE 5 is a longitudinal view of an overhead valve internal combustion engine having a tunable intake manifold between the carburetor and the cylinders with ionization and magnetic field of the present invention added for effecting improved air-fuel mixture;

FIGURE 6 is a longitudinal view in section of a mixing chamber in accordance with the present invention adapted to be used with a turbine or with an oil burner combustion chamber;

FIGURE 7 is a view in section similar to FIGURE 6 and which is provided with a series of separate ionizing stages and magnetic fields along the combustion chamber;

FIGURE 8 is a longitudinal side elevation view in section of a conventional ram jet engine modified in accordance with the present invention to provide improved mixing of the air and fuel prior to combustion;

FIGURE 8A is a partial end view of the lower pair of electrodes taken along lines A—A in FIGURE 8; and

FIGURE 9 is a longitudinal side view in elevation in section of a conventional turbojet modified in accordance with the present invention to provide one or more pairs of ionizing terminals and magnetic fields for acting upon the fuel-air mixture in the combustion chamber.

Referring now to FIGURES 1 and 2, the invention relates to an air-fuel mixing or combustion chamber 10 having tubes 12 which serve as means through which a liquid or gaseous fuel is fed into chamber 10 for mixing with an oxidizing element, such as air, that is supplied to the left hand side of chamber 10 as viewed in FIGURE 1 through suitable valve means 14. In accordance with the present invention, a superior atomization and mixture of the fuel and air is provided by applying an ionizing potential through electrodes 20 and 22 which extend through the walls of chamber 10 and the thoroughness of this mixture is further enhanced by application of a magnetic field at or near the place of ionization as by permanent magnets 24 and 26. The direction of the magnetic field is perpendicular to the current path between electrodes 20 and 22 of chamber 10.

The homogeneous diffusion or mixture of the fuel and air, which results in improved output through higher combustion efficiency of the fuel in an internal combustion engine or burner as will be described in greater detail below, is effected by first converting the particles or molecules in chamber 10 into charged ions at the region adjacent terminals 20 and 22. It appears that some dissociation of the molecules may occur. As the charged particles pass through the magnetic field supplied by magnets 24 and 26 along chamber 10 toward the region of low pressure as combustion takes place, there is induced in such charged ions or particles, a component of force resulting in movement of the charged particles in a direction perpendicular to the axial flow of the air-fuel mixture along chamber 10. The negatively charged particles and positively charged particles are deflected in opposite directions when moving through the magnetic field in a manner analogous to the movement of electrical charges in a conductor cutting the flux lines of a magnetic field in a dynamo which generates an electrical potential.

The walls of chamber 10 accordingly are made of non-magnetic materials, such as aluminum, or an insulating non-conducting plastic material, such as for example polyethylene or of a heat resistant, non-magnetic insulating material such as non-magnetic stainless steel where combustion takes place in chamber 10. The permanent magnets 24 and 26 may be a ferrite and polarized as shown in FIGURE 2 to provide a sufficient magnetic field across chamber 10. While various configurations of permanent magnets may be used to provide a magnetic field across chamber 10, I have found that the use of a pair of arcuately shaped magnets having the inner arcuate surface and the outer arcuate surface polarized in opposite directions as arked in FIGURE 2 is sufficient to materially improve the air-fuel mixture and the resulting efficiency of combustion.

Magnetic rubber, as developed by the Goodyear Company, may also be used by wrapping around and along the full length chamber 10, which it serves as a pre-ignition ionizing section and the temperatures are not too high, to advantage.

Electrodes 20 and 22 are made of a suitable conducting material that is not corrosive, such as copper or brass, and are preferably mounted through the walls of chamber 10 in such a manner as to be sealed and to be insulated from one another. If the walls of chamber 10 are electrically conductive, then insulation bushing 28 or rubber or like material is used around at least one of the electrodes 20.

The magnitude of the voltage applied to electrodes 20 and 22 depends upon the spacing between the electrodes.

With a spacing of about 50 millimeters, voltages on the order of from 5 to 100 or 200 volts are satisfactory for effecting ionization of the air-fuel mixture. In practice, I have found that 40 volts D.C. produces satisfactory ionization and that little or no increase in efficiency results from the application of higher voltages, or from the use of an alternating voltage. A battery 30 or other conventional source of D.C. voltage and variable resistor 31 may be used to supply the ionizing potential to electrodes 20 and 22.

The fuel and air mixing techniques discussed above may be used in conjunction with internal combustion engines of several types. For example, in FIGURE 3 block 32 may be part of an L-head type reciprocating piston engine having spark plug 34 may be generally of the type as illustrated in United States Patent No. 2,563,939. Each cylinder has an inlet port 36 and individual right angle pipe elbows 38 cast integrally with header 40 which extends longitudinally of the engine. Header 40 is provided with an inlet 42 which extends upwardly therefrom at the central portion of the manifold header 40 and is adapted to receive upon its upper end the usual form of air cleaner 43. In this embodiment, the fuel line is shown connected to a fuel feed tube 44, the end of which injects the fuel with the air at the region of electrodes 20 and 22, which are encompassed by the magnetic field supplied by the magnets as shown in FIGURES 1 and 2, magnet 24 only being illustrated in FIGURE 3. The mixing of fuel and air takes place not only by the usual turbulence, but the foregoing arrangement of parts is effective to produce the improved mixture of fuel and air with the resulting increase in the engine output due to improved efficiency of combustion.

In FIGURE 4 a similar arrangement is shown for feeding the air-fuel mixture to the fuel input manifold of and over-head valve type engine comprising a cylinder 50 having piston 52. In this embodiment the fuel inlet chamber 42 contains the electrical terminals 20 and 22 across which the ionizing potential is provided at the region of the magnetic field provided by the magnets, only magnet 24 being shown in FIGURE 4. Fuel is supplied through fuel feed tube 44 and air from air cleaner 43 in a conventional manner.

FIGURE 5 shows an embodiment of an internal combustion engine having the usual carburetor 62 for effecting the original air-fuel mixture and an intake duct 60 between carburetor 62 and a cylinder head having valve 64 and spark plug 66. Tube 60 is preferably formed of two or more telescoping sections 67 and 68 to be variable in length and the tube length is varied until the engine shows maximum performance. Such tubes in ordinary automobile engines should have a length in the range of from 25 to 45 inches between carburetor 62 and the intake valve 64.

A separate pair of ionizing electrodes 20 and 22 are mounted in each of tubes 67 and 68. In tube 68, the orientation of the electrodes 20 and 22 and the magnetic field are rotated 90° from the position of the correponding parts in tube 66. This orientation has the effect of more completely mixing the ionized particles to aid further in effecting a complete mixture of the fuel and air. By displacing the two sets of electrodes and magnetic fields 90° with respect to each other, the stream of air and fuel molecules passing along tube 68 at a position to be least affected by the ionizing potential will be in the maximum electric field provided by the terminals in tube 67.

With tubes of the foregoing length, it is preferable to provide more than one magnetic field since each time ionized or electrically charged particles pass through a magnetic field, additional mixing is provided. As ionization may be neutralized through the recombination of oppositely charged particles as the air-fuel mixture passes through duct 60 and to effect a more complete ionization and possibly dissociation prior to combustion, it is

desirable to place a second pair of ionizing electrodes downstream from the carburetor in tube 67 to effect a re-ionization of the air-fuel mixture before it passes through the downstream magnetic field.

The purpose of using a long duct 60 of variable length is to gain the advantage of the added pressure in duct 60 due to a reflected wave which will give a pulse of pressure above atmospheric, and a definite super charging effect on power and torque, where the total length of the intake duct is selected to get the pressure wave to the cylinder when the piston is at the end of the suction stroke. Such an arrangement results in optimum output from the engine due to a combination of a thoroughly mixed air-fuel mixture and to the added pressure in the piston due to the reflected wave through duct 60.

In each of the embodiments of 3, 4 and 5, electrodes 20 and 22 are obviously electrically insulated from one another as explained in connection with FIGURES 1 and 2, and the walls must be of a non-magnetic material as described above to provide a magnetic field across the mixing chamber.

In FIGURES 6 and 7, two embodiments of the present invention are illustrated wherein the ionization potential and magnetic field are applied either in the combustion chamber or at the position where combustion of the fuel-air mixture is initiated.

Considering FIGURE 6 first, the mixing or combustion chamber walls 70, which are preferably of a non-conducting, non-magnetic material are closed at the upstream end by a hemispherical section 72 through which fuel injection tube 74 and air supply tubes 76 and 78 are mounted. Ionizing electrodes 20 and 22 are of identical construction to that shown in FIGURE 1 and, if the material of wall 70 is an electrically conducting material, at least one of the terminals 20 or 22 must be insulated from wall 70. Permanent magnet 24 is the only magnet shown in this embodiment, magnet 26 being also present to provide a magnetic field across the mixing chamber at the region of the ionizing terminals 20 and 22 to effect a mixing of the fuel from nozzle 74 and air from tubes 76 and 78. Suitable means for producing an ignition spark such as spark plug 80 may be provided in walls 70 of the mixing chamber upstream of the ionizing terminals and magnetic field to thereby initiate combustion of the fuel and air mixture. A suitable nozzle, such for example as that shown in United States Patent No. 2,538,460 to Kaveny, may be provided at the downstream end to adapt this mixing chamber for use with a typical oil fired furnace whereby the flame, during operation would be downstream of terminals 20 and 22, or alternatively the combustion may take place at or about the location of terminals 20 and 22.

In the embodiment of FIGURE 7, three pairs of electrodes and separate magnetic fields are provided at spaced positions along the combustion chamber 70. Fuel is supplied through tube 74 and air is introduced into chamber 70 through louvres or slotted openings 82. Spark plug 80 is positioned in the hemispherical end wall 72 to cause ignition of the fuel and air mixture. Combustion is initiated at or slightly downstream of the first pair of electrodes 20 and 22. As combustion continues, the fuel and air mixture is further mixed by the second pair of electrodes 20′ and 22′ and by the third pair of electrodes 20″ and 22″ and their respective magnetic fields.

The second pair of electrodes 20′ and 22′ may be rotated through an angle of 120° relative to the orientation of the first pair of electrodes 20 and 22 as shown in FIGURE 7 and the third pair of electrodes 20″ and 22″ are then rotated through a further 120° to thereby be oriented symmetrically with respect to the orientation of the first two pairs of electrodes. The application of the ionizing potential along three axes, each rotated 120° with respect to the other, effects a helical path to the charged particles as they pass through the combustion

chamber and also a more complete ionization of the particles forming the air-fuel mixture.

At the locations of each of the three pairs of electrodes, the magnetic field extends across the combustion chamber in a direction perpendicular to the electric field between the electrodes 20 and 22, and is provided as by the arcuate magnets 24 and 26 which are rotated to have the same position relative to their respective electrodes. This has the effect of producing a further force on the electrically charged particles as they pass through the combustion chamber 70 in varying directions to thereby further reduce dead areas of poor circulation and mixing in the combustion chamber which result in pulsations and poor combustion.

In one embodiment where I have used multiple tandem magnetic fields and ionizing electrodes, a voltage of about 40 volts between electrodes 20 and 22 that were about 50 mm. apart and a longitudinal spacing between the pairs of ionizing electrodes or approximately 50 mm. were satisfactory. These dimensions are not critical, but are simply given by way of illustration.

In FIGURE 8, a ramjet is illustrated in longitudinal section, the conventional showing being modified by the addition of the means for providing magnetic field and the ionizing terminals in accordance with the present invention. The generally cylindrical outer shell 100 has an air entry or nose section 102 and a combustion chamber 104 with a centrally disposed air-fuel mixing chamber 106. If desired, an air guide cone 108 may be used to serve as a compressor. Near the rear portion of air guide cone 108, a fuel ring 110 is provided having nozzles 112 through which fuel is sprayed into mixing chamber 106. At the downstream end of mixing chamber 106, a flame holder 114 is provided which conventionally serves to hold the leading edge of the flame on the downstream side of flame holder 114 to prevent the flame from advancing into the mixing chamber 106.

Because of the relatively large diameter of the air-fuel mixing chamber 106, it has been found desirable to provide four ionizing electrodes 116, 118, 120 and 122. Alternate electrodes are connected to the same terminal on the voltage source as indicated in the drawings. Electrodes 116 and 122 on opposite side walls 100 are insulated from one another and preferably from walls 100 of mixing chamber 106. Electrodes 118 and 120 are arcuately shaped about center lines 124 and 126 with opposite ends thereof secured to the outer wall 100 of mixing chamber 106, a partial view of the lower pair of electrodes being shown in FIGURE 8A. The negative voltage on electrode 120 is supplied through lead 128, which may be supported at one end by air guide cone 108, and pass through the inside of the guide cone as illustrated and to the outside of walls 100 along a support member (not shown) for air guide cone 108. Ionizing electrode 118 is connected by lead 130 to a positive terminal on the voltage source through wires which are mounted similarly to wire 128.

The magnetic field may be provided by any conventional means that is effective for producing a magnetic field across chamber 106 of sufficient strength. In the illustrated embodiment, a pair of arcuate magnets are contemplated, though only magnet 24 is illustrated in FIGURE 8. By the present invention, a superior mixing of the fuel and air results in chamber 104 so that a greater thrust is obtained from the ramjet than is obtainable without the magnetic field and ionizing potential.

In FIGURE 9, the present invention is shown applied to a turbo-jet engine of generally conventional design, except for the use of ionization electrodes and the magnetic field. Such an engine conventionally comprises an air inlet or nose portion 140, downstream of which are fuel orifices 142 that supply fuel in an atomized condition, which then passes through compressor 144 into the combustion chamber. Combustion is effected by any conventional means, such as spark plug 146, and in this

embodiment the usual turbine 148 and nozzle 150, which in the drawings are diagrammatically illustrated are downstream of the combustion chamber. Around the combustion chamber are magnets 152 and 154 which provide a magnetic field across the combustion chamber at the region of the electrodes 156, 158, 160 and 162, these electrodes being connected to the respective negative and positive terminals of a D.C. source of voltage as indicated in the drawing. The magnetic fields and the electric fields may have the same orientation or, if desired, one or both of the fields at the downstream pair of electrodes may be reversed.

In this embodiment, the ionization and dissociation of the air and fuel molecules take place in the combustion chamber to thus effect a more complete burning of the fuel thereby resulting in a greater output force and higher efficiency than is provided without the use of the ionizing electrical terminals or the magnetic field.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. In combination, a chamber for mixing a combustible mixture of a plurality of elements, means for supplying each of said elements to said chamber, a pair of spaced electrical terminals mounted in walls of said chamber, means for applying an electrical potential to said terminals for effecting ionization of said elements, the magnitude of said potential being insufficient to cause arcing and means for applying a magnetic field across said chamber through which said ionized elements pass, the direction of the magnetic field being substantially perpendicular to the direction of an electric field resulting from application of the electrical potential to said terminals.

2. The combination as defined in claim 1 wherein said chamber includes means for effecting combustion of said elements in said chamber.

3. The combination as defined in claim 1 further comprising a combustion chamber and means for feeding said mixture of elements from said first-mentioned chamber to said combustion chamber before the effect of said ionization and magnetic field dissipate.

4. In combination, a chamber having generally cylindrical walls and open at opposite ends for mixing a combustible mixture of a plurality of elements, means for supplying each of said elements to one end of said chamber and for removing the mixture from the other end of said chamber, means for producing a magnetic field across said chamber, a pair of electrodes on opposite sides of the cylindrical wall, and means for connecting a voltage to said electrodes for effecting ionization of particles forming said elements at the location of said magnetic field, the magnitude of the voltage being insufficient to cause arcing, and the direction of said magnetic field being substantially perpendicular to a line between said electrodes.

5. In combination, a chamber having generally cylindrical walls and open at opposite ends for mixing a combustible mixture of a plurality of elements, means for supplying each of said elements to one end of said chamber and for removing the mixture from the other end of said chamber, means for producing a magnetic field across said chamber, a plurality of pairs of electrodes spaced along said chamber, the different electrodes of each pair being on diametrically opposite sides of the chamber walls, and means for connecting positive and negative terminals of a power supply across each pair of electrodes, the one electrode in each pair connected to one of the power supply terminals being displaced arcuately around the periphery of the tube from the one electrode of an adjacent pair of electrodes, and the magnetic field at each pair of electrodes being oriented to have its flux lines disposed in a direction substantially perpendicular to the ion current flow between said pair of terminals through the mixture.

6. In combination with a reciprocating piston engine of the type having a plurality of cylinders and pistons, means for supplying a gaseous fuel-air mixture for combustion in said cylinders comprising a fuel-air mixing chamber having non-magnetic walls with electrodes on opposite sides of said walls, means for producing a magnetic field across said chamber at the location of said electrodes, means for applying a voltage to said electrodes for effecting ionization of the fuel-air mixture, and means for supplying fuel and air to said mixing chamber.

7. Apparatus for increasing the efficiency of reaction of a gaseous mixture comprising in combination, a mixing chamber, an input duct for said chamber and through which said gaseous mixture passes into said chamber, ionizing means for said mixture embodying spaced ionizing electrodes mounted to ionize said mixture in a magnetic field between and through which said mixture is passed, the direction of said magnetic field being substantially perpendicular to the direction of an electric field between said electrodes.

8. Apparatus as set forth in claim 7 wherein said ionizing means embodies a plurality of magnetic field zones each having a pair of ionizing electrodes, said magnetic field zones being spaced along said duct through which said mixture passes successively, the direction of the magnetic and electric fields at successive zones in said duct being angularly displaced with respect to each other.

9. In a method of improving the combustion efficiency of a gaseous air-fuel mixture, the steps of applying an electric field to cause ionizing of said gaseous mixture, and directing said ionized gaseous mixture through a magnetic field at a location where ignition of said mixture occurs, said electric field being of insufficient magnitude to cause arcing.

10. The method as defined in claim 9 wherein the electric field is applied at the location of the magnetic field; and in a direction perpendicular to the direction of gaseous mixture flow.

11. The method as defined in claim 9 wherein the electric field is applied at the location of the magnetic field, and in a direction perpendicular to the direction of the magnetic field.

12. A method of reacting air-fuel fluid materials comprising the steps of: providing means having walls for guiding said fluid materials along an axial flow path; mixing the materials in said means by continuously subjecting particles forming said fluid materials to mutually perpendicular electric and magnetic fields that are also perpendicular to the axial flow of said material, the electric field being of insufficient magnitude to cause arcing; and immediately thereafter while the mixing effect of said electric and magnetic fields remains effective, causing combustion of said mixture.

13. Apparatus for increasing the efficiency of reaction of a gaseous air-fuel mixture comprising in combination with a combustion chamber, ionizing means for said mixture embodying spaced ionizing electrodes mounted to ionize said mixture in a magnetic field between and through which said mixture is passed, the direction of the magnetic field being substantially perpendicular to the direction of an electric field between said electrodes and the magnitude of the electric field being insufficient to cause arcing.

14. Apparatus as defined in claim 13 wherein the combustion chamber has an inlet and an outlet for the gaseous mixture to provide a flow path in a predetermined direction which is substantially perpendicular to the directions of both of said magnetic and said electric fields between said electrodes.

15. Apparatus for increasing the efficiency of reaction of a gaseous mixture comprising in combination with a mixing chamber, ionizing means for said mixture embodying a plurality of spaced magnetic field zones and spaced ionizing electrodes mounted to ionize said mixture in a magnetic field zone between and through which mixture is passed, the direction of the magnetic field being substantially perpendicular to the direction of an electric field between said electrodes, the ionizing electrodes being rotated relatively to one another along a path for said gaseous mixture and through which said mixture passes successively, and the magnitude of the electric field being insufficient to cause arcing.

16. Apparatus as defined in claim 15 wherein the mixing chamber has an inlet and an outlet for the gaseous mixture to provide a flow path in a predetermined direction which is substantially perpendicular to the directions of both of said magnetic and said electric fields between said electrodes.

17. Apparatus as defined in claim 7 wherein the mixing chamber has an inlet and an outlet for the gaseous mixture to provide a flow path in a predetermined direction which is substantially perpendicular to the directions of both of said magnetic and said electric fields between said electrodes.

References Cited in the file of this patent

UNITED STATES PATENTS

1,989,499	Sabot	Jan. 29, 1935
2,664,394	Reeves	Dec. 29, 1953
2,768,947	Weir	Oct. 30, 1956
2,926,276	Moriya et al.	Feb. 23, 1960

FOREIGN PATENTS

714,015	Great Britain	Aug. 18, 1954
814,269	Great Britain	June 3, 1959