XR 2,791,994

SEARCH ROOM

SUBSTITUTE FOR MISSING XR

May 14, 1957 D. A. GRIEB 2,791,994

ULTRASONIC MIXING METHOD AND APPARATUS

Filed Feb. 11, 1954 2 Sheets-Sheet 1

Fig. 1

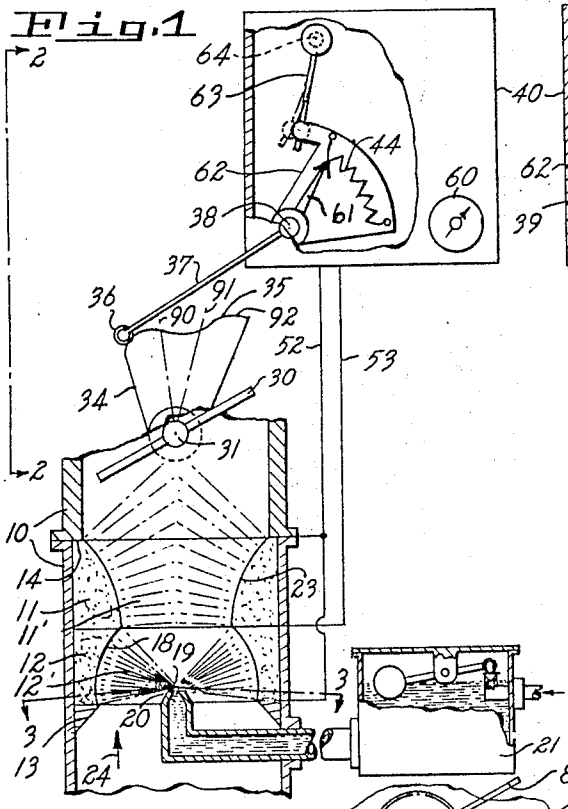


Fig. 2

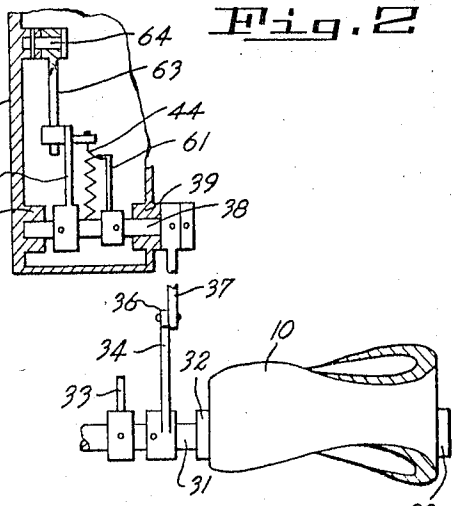


Fig. 3

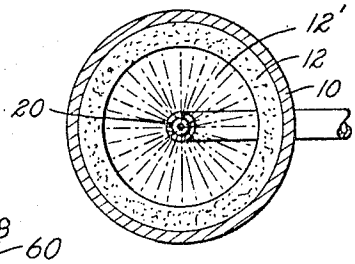


Fig. 4

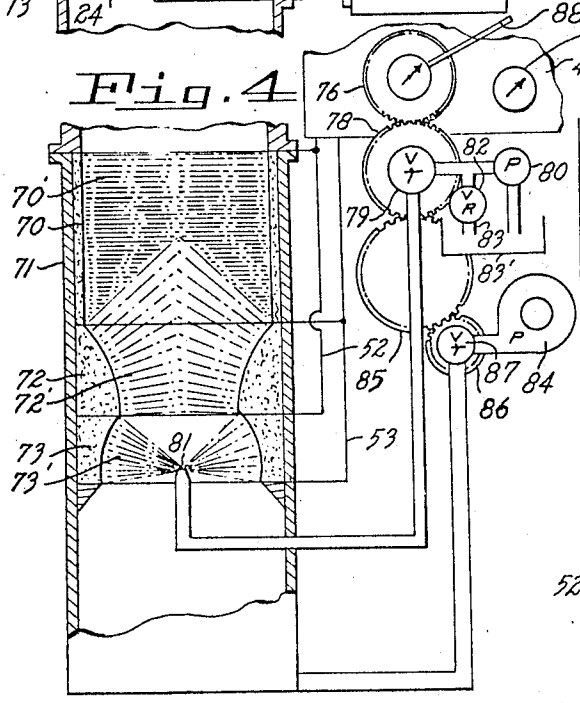
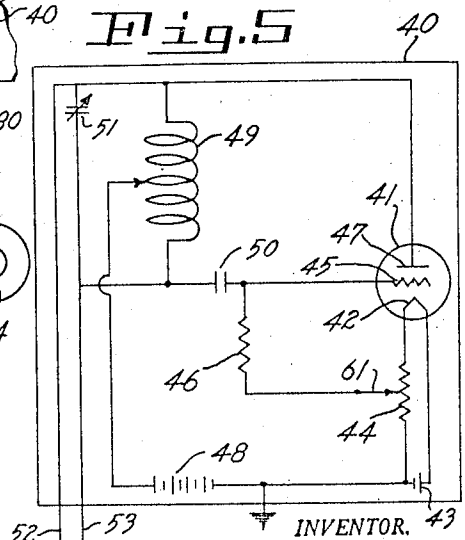


Fig. 5



INVENTOR.
DANIEL A. GRIEB.

BY
DES JARDINS, ROBINSON & KEISER.
Howard Keiser
HIS ATTORNEYS.

May 14, 1957 D. A. GRIEB 2,791,994

ULTRASONIC MIXING METHOD AND APPARATUS

Filed Feb. 11, 1954 2 Sheets-Sheet 2

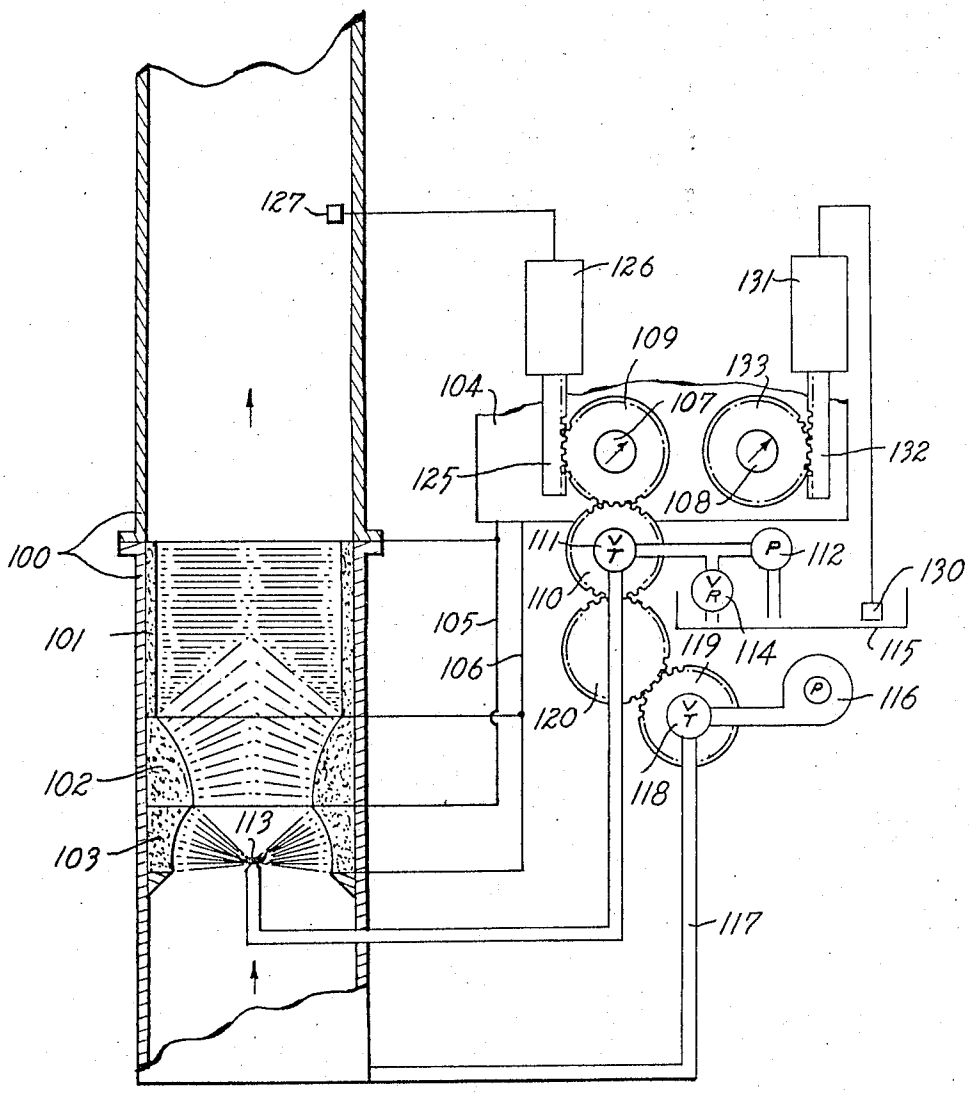


Fig. 6

INVENTOR.
DANIEL A. GRIEB.

BY
DES JARDINS, ROBINSON & KEISER.
Howard S. Keiser
HIS ATTORNEYS.

United States Patent Office 2,791,994 Patented May 14, 1957

2,791,994

ULTRASONIC MIXING METHOD AND APPARATUS

Daniel A. Grieb, Cincinnati, Ohio

Application February 11, 1954, Serial No. 409,620

23 Claims. (Cl. 123—119)

This invention relates to an improved method of and apparatus for continuously dispersing one material throughout another material. More particularly, the invention contemplates that the material to be dispersed, i. e., the discontinuous or discrete phase, shall be finely comminuted and thoroughly dispersed in a non-turbulent, continuously flowing stream of the material forming the continuous phase by applying a focused, controlled ultrasonic energy field to the discrete material at the point where it is introduced into the stream, the established, laminar flow pattern of the continuous phase material being preserved and maintained during the process. In accordance with my novel method of mixing, the ultrasonic energy is controlled by a predetermined set of conditions which give optimum results over a range of varied demands which result from the character of the particular application.

The invention also contemplates the continuous mixing of a non-turbulent stream of one material with a non-turbulent stream of another material by the application of ultrasonic energy to produce a homogeneous mixture of the two without disturbing the laminar flow characteristics of the confluent stream. In this case, the ultrasonic energy applied to the stream may be controlled both in frequency and in amplitude by means to be hereinafter described.

One possible application of my invention is in connection with the preparation of the fuel charge for internal combustion engines of the automotive type. 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. Today, however, our petroleum fuels are 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 obtain under various speeds and load conditions of the engine. As a result, an unstable engine charge is formed which readily coalesces into a liquid in the manifold. This liquid fuel is drawn into the combustion chamber where it causes fouling of the spark plugs and crankcase oil dilution. Present day low 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 small. To overcome this condition, present day carburetors are 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 chamber of the engine with resultant loss in efficiency. Also, special fuels having higher volatile fractions and anti-knock additions are commonly provided for winter driving.

To overcome these shortcomings of the present methods and devices utilized in the preparation of the fuel

charge for internal combustion engines, I have devised certain novel devices and procedures for preparing an ideal fuel charge under all driving conditions as will hereinafter be disclosed. In accordance with my invention, the various quantities of fuel required for the engine under different conditions of load is completely comminuted by the application of predetermined levels of ultrasonic energy which forces continuous formation of a stable fuel charge for the engine. The optimum frequency of the ultrasonic wave energy for emulsion stability and best engine performance is determined by a dynamometer test of each new engine and manifold design before quantity production is commenced. The ultrasonic energy is generated by a Venturi-shaped transducer which is designed to focus all of the ultrasonic energy upon the point of entry of the fuel stream into the air stream. These streams are coaxially arranged with one another and with the annular transducer which circumscribes the streams and permits laminar flow of the air stream and fuel charge to be maintained. The fuel charge is highly comminuted by virtue of the high-frequency energy applied thereto so that even low volatile fuel is easily ignited. Rapid burning of the charge is also obtained since the time required for combustion varies as the square of the particle diameter. Accordingly, higher operating speeds and increased compression ratios may be used with resulting increased power output of the engine. The reduction of particle size also reduces the possibility of vapor lock and the tendency of the fuel particles to coalesce when the velocity of the combustible mixture flowing through the intake manifold suddenly changes due to the opening and closing of the engine valves. The smaller the particles, the less their momentum and the less their tendency to coalesce on the walls of the manifold as liquid layers which will eventually reach the combustion chamber as raw fuel. Because all of the fuel is completely dispersed and finely comminuted by the controlled and direct application of high-frequency energy, the engine charge will behave more nearly like a perfect gas under the predetermined and correspondingly controlled set of conditions. Although in the present application my invention has been particularly described in connection with an automobile engine, it is understood that the novel features thereof apply equally well to all internal combustion engines and to turbo-jet engines.

It is well known that in many present day processes it is necessary to thoroughly disperse a finely divided solid or liquid into a fluid medium so as to obtain an intimate, homogeneous mixture of the discontinuous phase in the continuous phase. This type of mixing is required for the emulsification of oils and foods and for the mixing of the pigment with the vehicle in paint manufacturing. It is also increasingly important in the chemical industry in the continuous and intimate mixing of reagents whereby certain chemical reactions may be greatly accelerated by virtue of the enormous total area of a finely dispersed catalyst in the continuous phase reagent, in controlling the size of polymers, and in dissolving solutes which are not readily soluble in the solvent material. It is well known today that this intimate mixing of materials can be accomplished by subjecting them to high-frequency vibrations produced by ultrasonic waves, with resultant agitation and heating of the materials. Heretofore, as a practical matter, this mixing has been effected by the batch method in which suitable quantities of the materials to be mixed are placed in containers and subjected to the energy of the high-frequency waves. I have now, however, devised a thoroughly workable and practical means whereby a continually flowing stream of the materials to be mixed may be subjected to the concentrated energy of ultra-

sonic vibrations so as to provide for continuous processing of the materials rather than by discontinuous processing thereof as in the former methods. The particular frequency of the ultrasonic energy that is applied may be controlled in accordance with the characteristics of the final product produced by the mixing. At the same time, the amplitude of the ultrasonic energy may be regulated by the temperature of the dispersed or discrete phase before it is injected into the mixing process.

Accordingly, it is an object of my invention to force greater comminution of the liquid fuel of an internal combustion engine for all load conditions and to thoroughly disperse the particles of fuel in the air stream to form a stable fuel charge for the engine.

Another object of my invention is to incorporate a transducer capable of operating at ultrasonic frequencies in the wall of an engine intake manifold thereby eliminating any obstruction to the passage of fuel charge therethrough and effecting a thorough dispersion of said charge.

Another object of my invention is to shape the transducer in the form of a Venturi tube whereby the concentrated ultrasonic energy may be concentrated at the point where the fuel is sprayed into the intake air to force complete comminution. The impingement of the concentrated ultrasonic energy on the fuel also heats the same and aids in the volatilization thereof.

Another object of my invention is to shape the transducer so as to focus or concentrate the ultrasonic wave energy on the tip of the nozzle from which the fuel is sprayed. This concentrated energy, in addition to the heat generated thereby, causes atomization of the fuel at the instant it enters the intake manifold and overcomes the cohesive and adhesive forces of the fuel thereby effectuating the removal of the fuel from the nozzle and dispersal of same into the air stream.

Another object of my invention is to scientifically control the preparation of the correct fuel charge by the dispersal of fuel through the application of ultrasonic energy at the point where the fuel enters the air stream. The addition of ultrasonic energy may be controlled in accordance with the specific load requirements of the engine. This may be accomplished by varying the amplitude of vibrations produced by the transducer, the greater the amplitude, the greater the amount of fuel which will be dispersed in, and thoroughly mixed with, the air stream thereby resulting in an increase in power, fuel efficiency and acceleration responsiveness. This feature of the invention eliminates the need for additional jets, special, complicated accelerating systems in carburetors, and fuel additives which, in the past, have been necessary in order to obtain from the engine the power required for rapid acceleration.

Another object of my invention is to provide the particular frequency of ultrasonic energy that will give maximum power output of the engine and optimum acceleration response for all conditions.

Another object of my invention is to automatically compensate the effective fuel-air ratio for different ambient temperatures thereby insuring most efficient operation of the engine under various temperature conditions.

Another object of my invention is to provide an improved method and apparatus for continuously and uninterruptedly mixing one substance with another with the aid of ultrasonic vibrations to produce a homogeneous mixture or stable emulsion of the two substances.

Another object of my invention is to control the continuous mixing or dispersing of substances by regulating the amplitude of the ultrasonic energy in accordance with the temperature of the solute or discontinuous phase and to control the frequency of the applied ultrasonic energy in accordance with a particular property, for example the temperature, of the final product which is produced by the mixing, or a reaction product thereof.

With these and other objects in view which will become apparent from the following description, the invention includes certain novel features of construction and combinations of parts, the essential elements which are set forth in the appended claims and a preferred form or embodiment of which will hereinafter be described with reference to the drawings which accompany and form a part of this specification.

In the drawings:

Fig. 1 is a schematic view illustrating the application of my invention to an internal combustion engine of conventional design.

Fig. 2 is a view taken along the line 2—2 in Fig. 1.

Fig. 3 is a cross-sectional view taken along the line 3—3 in Fig. 1, which illustrates the concentrating or focusing of the ultrasonic energy field upon the fuel nozzle located at the center of the Venturi.

Fig. 4 is a view similar to Fig. 1 in which my invention is shown as applied to an engine in which the fuel and air are both introduced into the intake manifold under pressure and in which the amount of fuel, air and ultrasonic energy supplied are governed by a single control.

Fig. 5 is a wiring diagram of a generator of high-frequency current used for driving the transducers shown in Figs. 1, 4 and 6.

Fig. 6 is a schematic view of an apparatus for effecting continuous mixing of substances by the application of ultrasonic energy, the amount of energy applied being controlled by the temperature of the discrete phase medium and the frequency of the energy being controlled by the condition of the final product.

In Fig. 1 of the drawings is shown an intake air conduit **10** of an internal combustion engine which has mounted therein a pair of annular transducers **11** and **12** thereby forming an assembly of coaxial parts for effecting laminar flow. In the present instance, the transducers are held in place within the conduit by means of a clamping ring **13** which holds them against a shoulder **14** formed in the conduit **10**. The transducers may be formed of any suitable material having piezoelectric properties and which can be given the form of an annulus. In the present instance, I contemplate the use of any of the well-known ceramic transducer materials which may be made in the form of cylinders or annuli and rendered piezoelectric by special polarizing treatments during manufacture. It is to be understood, of course, that I do not wish to restrict myself to this particular type of material and that the transducers **11** and **12** may be formed of any substance, including silicon, which can be caused to undergo rapid changes in thickness or volume under the influence of an oscillatory electric current. The transducer **12** is preferably provided with a concavity **18** whose center of curvature lies at the point **19** which coincides with the tip of a nozzle **20** of a carburetor **21** which may be of conventional design. The interior face of the transducer **11**, on the other hand, is provided with a convex surface **23** as shown in the drawing. As a consequence, the ultrasonic energy field **12'** produced by the transducer **12** will be focused or concentrated at the tip of the nozzle **20**, while the ultrasonic energy field **11'** produced by the transducer **11** will not be concentrated at a particular point but rather along the longitudinal axis of the conduit **10** with a component in the direction of flow of the air-fuel mixture through the conduit as indicated by the arrow **24**.

The speed of the internal combustion engine may be controlled in the conventional manner by means of a throttle valve **30** mounted within the conduit **10** on a transverse shaft **31** (see also Fig. 2) which is journaled in bushings **32** secured to the walls of the conduit. Control of the valve from a remote position may be effected by means of suitable linkage including a control rod **33** secured to the shaft **31**.

Also mounted on the shaft 31 is a plate cam 34 which is provided with a graduated surface 35 along which a roll 36 is adapted to ride. The roll 36 is journaled on the end of an arm 37 which is secured to a shaft 38 journaled for rotation in bushing 39 supported within a casing 40. This casing may form the housing for the generator of high-frequency electrical current for driving the transducers 11 and 12. As shown in Fig. 5, this generator may comprise a Hartley oscillator together with suitable amplifying stages (not shown) for supplying the necessary power required for driving the transducers at high energy levels.

As shown in Fig. 5, the Hartley circuit comprises a three element vacuum tube 41 having a filament 42 heated by a source of current 43. A voltage drop is produced across the resistance winding of a potentiometer 44 connected in the filament circuit which serves as a source of bias for the grid 45 of the vacuum tube. This biasing of the grid is accomplished by connecting the grid to the slider of the potentiometer through a gridleak resistance 46. The plate 47 of the vacuum tube is supplied with suitable positive potential from a voltage source 48 which is connected to the plate through a selector tap on an inductor 49. A portion of the oscillatory energy in the plate circuit is fed back to the grid 45 through the lower end of the inductor 49, the grid being isolated from the plate voltage by a small condenser 50. The amount of feed-back to the grid may be determined by adjustment of the selector tap on the inductor. The frequency of oscillation may be adjusted by tuning of the variable condenser 51 which is connected in parallel with the inductor 49 to provide a parallel-resonant circuit. The output of the generator is applied to the transducers through leads 52 and 53. The vacuum tube oscillator heretofore described is by way of example only, it being understood that high-frequency generators employing point contact or junction transistors could be used in place thereof if desired.

The shaft of the tuning condenser 51 is provided with a tuning knob or dial 60 so as to permit the frequency of the current generated by the generator to be varied as desired. The frequency of the current generated by the oscillator circuit should be adjusted to a point where maximum efficiency is obtained from the engine. This will probably lie within the range of from 50 kilocycles upwards to one megacycle and it is to be understood that I do not wish to restrict the present invention to any particular frequency or range of frequencies. Rather it is the adjustability of the frequency generated to match the requirements of the particular internal combustion engine or to obtain peak performance from the engine which is the desideratum rather than the particular frequency at which this occurs.

Referring to Fig. 5, it will be recalled that the electronic oscillator circuit there shown is provided with a grid biasing arrangement including potentiometer winding 44 and a sliding contact which is designated by reference numeral 61. The amplitude of the oscillatory current produced by the generator, that is the power output thereof, may be controlled by varying the bias on the grid 45 by adjustment of the sliding contact 61. As shown in Figs. 1 and 2, the contact 61 is carried by the shaft 38 which is rocked by cam 34. Hence, by suitably shaping the face 35 of the cam, varying output of the high-frequency generator may be determined by the position of the throttle valve 30. In order to automatically compensate the system for different ambient temperatures, the potentiometer resistance winding 44 is preferably carried by a rockable supporting plate 62 which is journaled on the shaft 38. The plate 62 is connected to the free end of a bimetallic temperature responsive element 63 which is secured at its other end to a stationary supporting post 64. Hence, with changes in temperature, the resistance winding 44 will be adjusted relative to the sliding contact 61 to compensate the power output of the generator for changes in the ambient temperature.

In Fig. 4 of the drawings is shown a modification of the invention illustrating the manner in which it may be applied to an internal combustion engine in which both the air and fuel are supplied under pressure produced by suitable pump means. Also, as shown in this figure, a plain cylindrical transducer 70 is provided in the air intake conduit 71 to augment the agitation of the fuel-air mixture within the conduit after it passes through the Venturi provided by the transducers 72 and 73 which correspond to the transducers 11 and 12, respectively, heretofore described. The transducers 70, 72 and 73 provide ultrasonic energy fields 70', 72' and 73' respectively. In the modified form of apparatus, the sliding contact 61 of the potentiometer 44 is carried by a shaft on which a gear 76 (Fig. 4) is secured. The gear meshes with a gear 78 secured to the shaft of a valve 79 which controls the flow of fuel under pressure from a pump 80 to a nozzle 81 located in the Venturi in the intake conduit which is formed by the transducers 72 and 73. A relief valve 82 is provided for the pump 80 to bypass fuel through a line 83 to a reservoir 83' when the pressure on the delivery side of the pump exceeds a predetermined value. In this modification, air is supplied to the intake conduit under pressure by a pump 84 which may be of any suitable type capable of handling the air requirements of the engines. The flow of the air is controlled by throttle valve 87 which is operated by a throttle lever 88 through a train of gears 76, 78, 85 and 86.

The operation of the two forms of apparatus is believed clear from the foregoing description thereof and probably little more need be said with regard thereto. As previously mentioned, the frequency control 60 of the generator is manipulated until a point is reached where the most efficient operation of the engine is achieved. The frequency is permitted to remain at this preselected value and need not ordinarily be readjusted. As shown in Fig. 1, when the engine is idling at closed throttle, a low point on the cam 34 lies beneath the roll 36 so that the power output of the generator is reduced to give the proper fuel-air ratio for idling conditions. In other words, when the engine is operating at reduced power, less fuel will be demanded by the engine and, hence, less ultrasonic energy will be needed to overcome the cohesive and adhesive forces of the fuel at the tip of the nozzle.

When the throttle valve 30 is moved from the idling position shown in Fig. 1 to the cruising range defined by the portion of the cam lying between the lines 90 and 91, the surface of the cam lying between the position occupied by the roll 36 in Fig. 1 and the line 90 will move beneath the roll and cause an increase in the power output of the generator due to movement of the contact arm 61 to the right (Fig. 1). This will decrease the bias on tube 41 and increase the power output of the generator to provide a richer mixture for acceleration from idling to cruising speed. The portion of the cam lying between the lines 90 and 91, i. e., the cruising range of the device, is a low point on the cam and the power output of the generator is again reduced as the sliding contact 61 is moved upwardly (Fig. 1) toward the top of the winding of potentiometer 44 thereby increasing the bias on the vacuum tube 41 and decreasing the power output of the high-frequency generator. This decreases the discharge of fuel from the nozzle and provides proper preparation of the charge for cruising operation. Within the cruising range, the energy level of the generator is somewhat reduced inasmuch as a leaner mixture is desired at cruising speed by virtue of overall efficiency. As the throttle is moved from the cruising range into the high speed range, indicated by reference numeral 92, the energy output of the generator is increased to a maximum to provide the

proper air-fuel ratio necessary for maximum power output of the engine.

Thus, in effect, the profile of cam 34 is a reproduction of a fuel and engine-speed polar coordinate curve. Hence, the object of controlling the application of ultrasonic energy by a scientifically predetermined set of conditions which give optimum final results over a range of varied demands which are characteristic of the particular application is accomplished.

In Fig. 1, the bimetallic strip 63 is shown in the position which it occupies during warm weather, the strip having the effect of moving the sliding contact 61 toward the upper end of the winding 44 to increase the bias on tube 41 and decrease the power output of the generator. However, if cold weather is encountered, the strip will bend to the left and, in effect, move the contact 61 toward the lower end of the winding 44 thereby decreasing the bias and increasing the power output of the generator so as to provide an enriched mixture for winter driving.

In Fig. 6 of the drawings I have shown a modified form of my invention in which the frequency of the ultrasonic vibrations produced by the transducers is controlled by the temperature or other desired physical properties of the final mixture while the amplitude of the vibrations generated by the transducers is controlled by the temperature of the solute or material forming the discontinuous phase, as the case may be. As shown in Fig. 6, a mixing tube or conduit 100 is fitted with transducers 101, 102 and 103 which, in general, correspond with the transducers 70, 72 and 73 illustrated in Fig. 4. The transducers of Fig. 6, like the transducers of Fig. 4, may be supplied with high-frequency electric current from an ultrasonic generator 104 through the leads 105 and 106 in the same manner as the transducers in the modification shown in Fig. 4. The frequency of the current produced by the generator may be controlled by the manipulation of a dial 107 in a manner similar to that employed by the dial 60 of the generator 40. Likewise, the amplitude of the output current of the generator may be controlled by manipulation of dial 108 which may control the operation of the generator in a manner similar to that employed in the case of the gear 76 (Fig. 4). The dial 107 is provided with a gear 109 which meshes with a gear 110 fastened to the shaft of a throttle valve 111 which controls the flow of the solute or discontinuous phase material from a pump 112 to a nozzle 113 located in the Venturi formed by the transducers 102 and 103. As in the case of the apparatus shown in Fig. 4, a relief valve 114 is provided for the pump 112 to bypass the solute or discontinuous phase medium through a return line to an accumulator or reservoir 115 when the pressure on the delivery side of the pump exceeds a predetermined value. The material forming the continuous phase medium may be injected into the mixing tube under pressure by means of a pump 116 which may be connected in any suitable manner with the supply of such material in order to deliver it under pressure to a delivery line 117 connected with the mixing tube. The flow of material from the pump into the line 117 is controlled by a suitable throttle valve 118, which, in turn, is controlled by the positioning of the valve 111 by means of gears 119 and 120 which mesh with the gear 110.

Meshing with the gear 109, which controls the frequency of the generator, is a rack 125 which is operated by an actuator 126 that responds to the condition prevailing in the mixing tube as sensed by the condition responsive element 127. Thus, if the frequency of the generator is to be controlled by the temperature prevailing in the mixing tube, the element 127 may be a pressure bulb connected with an expansible member, such as a bellows, in the actuator 126 which operates the rack 125. If the character of the mixing process is such that the temperature of the final mixture will vary inversely as the particle size of the comminuted material forming the discrete phase, an increase in temperature as sensed by the element 127 will cause the actuator 126 to rotate the frequency control dial 107 in such a direction as to decrease the frequency, and vice versa. In this way, changes in the properties of the final mixture may be utilized to effect automatic control of the mixing process.

Also, it may be desirable to control the amount of energy supplied by the transducers to the materials in the mixing tube in accordance with the temperature of the solute or discontinuous phase medium contained in the reservoir 115. For this purpose, a temperature responsive element such as a pressure bulb 130 may be connected with an actuator, such as an expansible bellows, which is operatively connected with a rack 132 meshing with a gear 133 secured to the amplitude control dial 108. Hence, as the temperature of the material in the reservoir 115 increases, the actuator 131 may be caused to rotate the dial 108 in such a direction as to decrease the amount of energy supplied by the transducers to the materials in the mixing tube thereby stabilizing the operation of the mixing process. It is obvious that, if desired, conditions other than changes in temperature could be utilized for controlling the frequency and amplitude of the ultrasonic generator 104 to exert the desired control of the process of mixing the materials effected by the apparatus herein disclosed.

While I have described my invention in connection with several possible forms or embodiments thereof, and have used, therefore, certain specific terms and language herein, it is to be understood that the present disclosure is illustrative rather than restrictive and that changes and modifications may be resorted to without departing from the spirit or the scope of the claims which follow.

Having thus described my invention, what I claim as new and useful, and desire to secure by United States Letters Patent, is:

1. The method of continuously mixing together two fluids to produce an intimate and homogeneous mixture of the same comprising the steps of passing a laminar, non-turbulent stream of one of said fluids through an enclosed channel, introducing the other fluid into the center of the channel with a minimum of disturbance to the stream flow of the first fluid, and then concentrating ultrasonic energy upon the point of emergence of said other fluid into the stream of said one fluid by focusing a field of ultrasonic energy thereon while maintaining the laminar flow of said one fluid through the channel.

2. The method of continuously mixing together two fluids to produce an intimate and homogeneous mixture of the same comprising the steps of passing a laminar, non-turbulent stream of one of said fluids through an enclosed channel, introducing the other fluid into the center of the channel with a minimum of disturbance to the laminar flow of the first fluid, and then agitating said other fluid at its point of emergence into the stream of said one fluid by focusing thereon ultrasonic vibrations generated about the periphery of the channel.

3. The method of claim 2 including the step of controlling the amplitude of the ultrasonic vibrations applied to the fluids in accordance with a set of predetermined conditions for producing optimum results.

4. A liquid fuel dispersing device for internal combustion engines comprising an air intake conduit, a nozzle for spraying liquid fuel into said conduit, an annular transducer situated within said conduit and forming a portion of the interior wall thereof, said transducer being shaped to form a Venturi within said conduit, and means for driving said transducer at an ultrasonic frequency to violently agitate the fuel and air mixture within said conduit and cause the fuel to be finely comminuted and thoroughly dispersed in the intake air.

5. The dispersing device of claim 4 wherein said nozzle is located in the Venturi and said transducer is

shaped to focus the energy generated thereby on the end of said nozzle.

6. The dispersing device of claim 5 wherein said transducer is provided with a portion shaped to direct the energy generated thereby both inwardly toward the center of said conduit and also axially in the direction of flow of the fuel-air mixture passing therethrough.

7. The dispersing device of claim 4 including a throttle valve, and means for controlling the energy supplied to said transducer by said driving means in accordance with the position of said valve.

8. The dispersing device of claim 7 wherein said controlling means includes a non-linear driving connection between said valve and said driving means.

9. The dispersing device of claim 4 including a temperature responsive device for controlling the energy supplied to said transducer by said driving means in accordance with the temperature of the ambient air.

10. The dispersing device of claim 9 including a throttle valve, and means for controlling the energy supplied to said transducer by said driving means jointly by said temperature responsive device and said valve.

11. The method of controlling the application of ultrasonic energy to the preparation of the fuel charge of an internal combustion engine so as to obtain maximum power output from the engine under varying conditions of load comprising the steps of determining the amount of ultrasonic energy which must be applied to the fuel charge to produce maximum power output from the engine for each of a number of different settings of the throttle valve, and utilizing the information thus obtained to continuously vary the amount of ultrasonic energy applied to the fuel charge with changes in the throttle position to obtain maximum performance from the engine under all conditions of load.

12. The method of preparing an engine fuel charge as recited in claim 11 including the step of concentrating the ultrasonic energy at the point of mixing of the engine charge while maintaining a constant, laminar flow of the charge to the engine.

13. The method of preparing an engine fuel charge as recited in claim 11 including the step of modifying the amount of ultrasonic energy applied to the fuel charge in accordance with changes in the ambient temperature.

14. The method of controlling the application of ultrasonic energy to the preparation of the fuel charge of an internal combustion engine so as to secure optimum performance from the engine for different load conditions comprising the steps of determining the amount of ultrasonic energy which must be applied to the fuel charge to produce maximum power output from the engine for each of a number of different settings of the throttle valve, and utilizing the information thus obtained to determine the profile of a cam moving with the throttle valve for controlling the power output of the ultrasonic energy generator.

15. The method of claim 14 including the steps of dividing the cam into sections corresponding with particular load ranges of the engine, and contouring each of said cam sections so as to provide the ultrasonic power needed to satisfy the power requirements of the engine for that particular load range.

16. The method of preparing a fuel charge for an internal combustion engine by use of ultrasonic energy which consists in determining the frequency of the ultrasonic energy which produces optimum results for a given combination of engine design and fuel, applying ultrasonic energy at said frequency to the fuel charge, varying the amplitude of the energy so applied to determine the particular value of amplitude which produces the maximum horsepower output for each load condition of the engine, producing a plate cam having a curved rim which represents in polar coordinates the particular values of amplitude producing maximum horsepower output for each load condition of the engine, and driving the cam and the throttle valve of the engine by an accelerator pedal while the curved rim of the cam drives the amplitude control of the ultrasonic energy generator to automatically reproduce any of the maximum horsepower outputs for each condition of speed in increasing or decreasing value depending upon the direction of drive of the cam.

17. The method of continuously and uninterruptedly mixing together a plurality of fluids to produce an intimate and homogeneous mixture of the same composing the steps of combining the fluids and passing them through an enclosed channel, generating ultrasonic energy around the periphery of the channel and directing the energy inwardly toward the center of the channel to thereby thoroughly agitate and intimately mix together the fluids passing therethrough, regulating the amplitude of the applied ultrasonic energy in accordance with the temperature of the fluids and regulating the frequency of the applied ultrasonic energy in accordance with a property of the final mixture produced by the method.

18. Apparatus for continuously and uninterruptedly mixing together a plurality of fluids to produce a homogeneous mixture of the same comprising a conduit through which the fluids to be mixed may be passed, an annular transducer received within said conduit and forming a portion of the wall thereof, means for driving said transducer at an ultrasonic frequency to violently agitate the fluids passing through the conduit and to thoroughly and intimately mix the same, a nozzle for injecting one of the fluids to be mixed into said conduit adjacent said transducer, and means on said transducer for focusing the high-frequency energy produced thereby on the end of said nozzle.

19. The apparatus of claim 18 wherein said transducer is shaped so as to form a Venturi within said conduit and said nozzle is located in the Venturi.

20. The apparatus of claim 18 wherein said transducer is composed of silicon.

21. The method of continuously mixing together two fluids to produce an intimate and homogeneous mixture of the same comprising the steps of passing a laminar, non-turbulent stream of one of said fluids through an enclosed channel, introducing the other fluid into the center of the channel with a minimum of disturbance to the laminar flow of the first fluid, agitating the fluids in the channel by means of ultrasonic vibrations generated about the periphery of the channel, controlling the amplitude of the ultrasonic vibrations applied to the fluids in accordance with a set of predetermined conditions for producing optimum results, and modifying the control of the amplitude of the ultrasonic vibrations in accordance with variations in the surrounding ambient temperature.

22. The method of continuously mixing together two fluids to produce an intimate and homogeneous mixture of the same comprising the steps of passing a laminar, non-turbulent stream of one of said fluids through an enclosed channel, introducing the other fluid into the center of the channel with a minimum of disturbance to the laminar flow of the first fluid, agitating the fluids in the channel by means of ultrasonic vibrations generated about the periphery of the channel, and controlling the amplitude of the ultrasonic vibrations applied to the fluids in accordance with the temperature of an ingredient thereof prior to mixing.

23. The method of continuously mixing together two fluids to produce an intimate and homogeneous mixture of the same comprising the steps of passing a laminar, non-turbulent stream of one of said fluids through an enclosed channel, introducing the other fluid into the center of the channel with a minimum of disturbance to the laminar flow of the first fluid, agitating the fluids in the channel by means of ultrasonic vibrations generated about the periphery of the channel, and controlling the frequency of the ultrasonic vibrations applied to the fluid

in accordance with variations in a property of the final product resulting from the mixing process.

References Cited in the file of this patent

UNITED STATES PATENTS

1,939,302	Heaney	Dec. 12, 1933
2,453,595	Rosenthal	Nov. 9, 1948
2,454,900	Vang	Nov. 30, 1948
2,565,159	Williams	Aug. 21, 1951
2,578,505	Carlin	Dec. 11, 1951
2,592,703	Jaffe	Apr. 15, 1952

FOREIGN PATENTS

508,582	Great Britain	July 4, 1939