April 22, 1958 J. K. COMPTON 2,831,666

MIXING DEVICE

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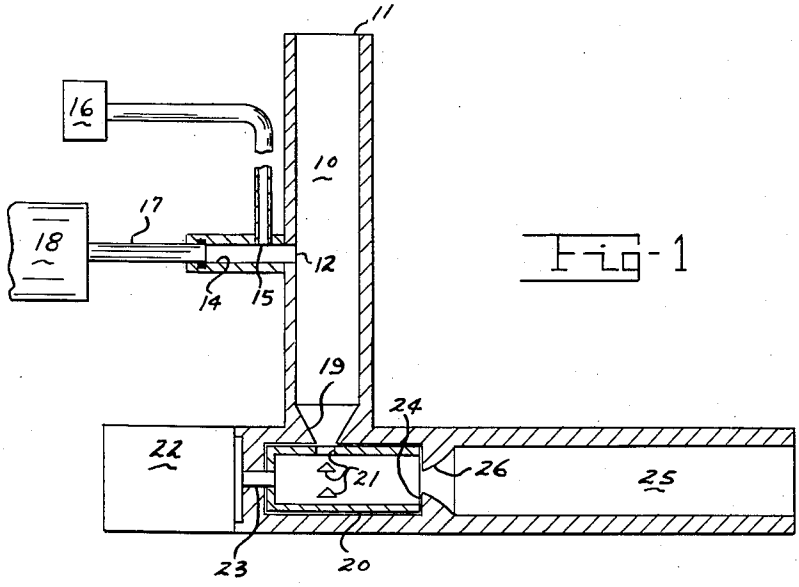

Fig-1

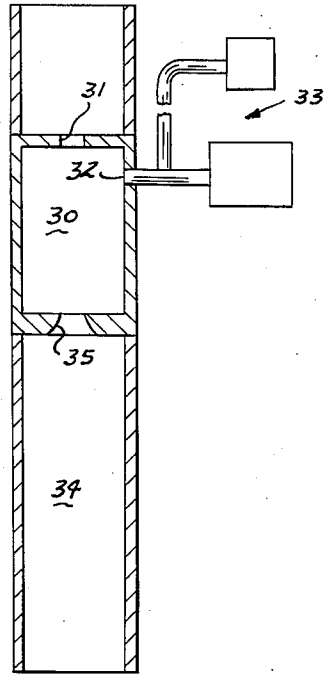

Fig-2

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MIXING DEVICE

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7 Claims. (Cl. 261—1)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to a device for mixing a gas and a liquid and, more particularly, to a device that employs ultrasonic oscillations to mix a liquid and a gas.

In mixing a gas and a liquid such as air and fuel for a jet engine, it is desired that there be optimum distribution of the fuel throughout the air. However, the large quantity of fuel required by a jet engine results in the fuel flowing at a rapid rate so that only a minimum period of time exists for mixing. This presents a problem when it is desired that the distribution of the fuel throughout the air be at an optimum. Obviously, if there is not sufficient mixture of the fuel and air, the mixture must be fuel rich in order to insure combustion within the jet engine. The present invention satisfactorily solves this problem by creating oscillations of an ultrasonic frequency to break down the stability of the liquid whereby the liquid mixes with the gas at an optimum. The particular ultrasonic frequency, of course, depends on the stability of the liquid and the amount of mixing desired.

An object of the present invention is to provide a device for optimum mixing of a rapidly flowing liquid and a gas in a minimum of time.

Another object of this invention is to provide a device for mixing of a liquid and a gas at an ultrasonic frequency.

Other objects of this invention will be readily perceived from the following description.

This invention relates to a device for mixing a liquid and a gas comprising a resonant chamber to which liquid and gas are supplied. The quantity of liquid supplied to the resonant chamber is regulated. The resonant chamber creates oscillations in the ultrasonic range to mix the gas and the liquid. Suitable means connect the outlet of the resonant chamber with an open ended tube, which is in resonant frequency with the oscillations in the resonant chamber. The connecting means matches the resonant chamber with the open ended tube whereby there is a maximum transfer of energy therebetween.

The attached drawing illustrates preferred embodiments of the invention, in which:

Fig. 1 is a sectional view partly in elevation of one form of the mixing device of the present invention; and

Fig. 2 is a sectional view partly in elevation of another embodiment of the mixing device of the present invention.

Referring to the drawing and particularly Fig. 1, there is shown a mixing chamber 10 having an opening 11 through which a gas, such as air, is supplied under pressure. The mixing chamber has a second opening 12 through which a liquid, such as fuel, is supplied in a predetermined quantity. The liquid is supplied to the mixing chamber 10 from a cylinder 14 of a liquid metering valve. The cylinder 14 has an inlet 15 transverse to its axis. The inlet 15 is connected to a liquid source 16 under suitable pressure to permit liquid to enter the cylinder 14 through the inlet 15 and then to be pumped from the cylinder through its outlet and the opening 12 into the mixing chamber 10. A piston or plunger 17, which moves within the cylinder 14, is preferably connected to a solenoid 18 although the piston could be driven mechanically, if desired. The solenoid may be either the electromagnetic or electrostatic or piezo-electric type; it is only necessary that the solenoid create a reciprocating action by the piston 17 with the cylinder 14.

The metering of the liquid into the mixing chamber through the opening 12 creates some mixing of the liquid and the gas before it flows from the mixing chamber 10 through its outlet 19 into a resonant chamber, which is preferably a rotating drum or cylinder 20 having a plurality of openings 21 in its wall. The openings 21 are designed to create oscillation of ultrasonic frequencies on the mixture of liquid and gas flowing therethrough into the interior of the drum 20.

The drum 20 is driven by a motor 22 connected thereto by a shaft 23. The motor may be either pneumatic or mechanical or electrical as desired. The speed of the rotating drum 20 is such that it generates transverse and longitudinal waves at an ultrasonic frequency such as 25 kilocycles, for example. The frequency may be changed by varying the speed of the rotating drum 20 or the number of openings 21; an increase in the speed of the drum or the number of openings increases the frequency. The outlet 24 of the rotating drum 20 communicates with an open ended tubular member 25 through a connecting passage 26. The passage 26 is an exponential flare, which means that the cross-sectional area of the passage 26 increases exponentially with distance from its inlet adjacent the outlet 24 of the drum 20, that matches the frequency generated by the drum to free space. The design of the passage 26 as an exponential flare permits transition of the resonant frequency waves generated in the rotating drum 20 to the open ended tube 25, which is in resonant frequency with the oscillations produced within the drum 20, with minimum attenuation. The minimum requirement for the largest portion of the passage 26 is that the circumference at the largest portion is equal to at least one wavelength of the lowest frequency to be produced within the drum 20. In order to obtain the maximum wave amplitude for optimum mixing of the liquid and the gas, the drum 20 is designed to have a length equal to an odd quarter wavelength.

Considering the operation of the mixing device of Fig. 1, the gas is supplied to the mixing chamber 10 through the opening 11 at a greater pressure than exists at the outlet of the open ended tubular member 25. The liquid is metered into the mixing chamber 10 through the opening 12. The amount of liquid entering the mixing chamber 10 may be varied by varying the stroke of the piston 17, which is accomplished by varying the amplitude of the solenoid 18, or by varying the frequency of the piston stroke, which is accomplished by varying the frequency of the solenoid 18, or by varying both. The quantity of liquid metered into the mixing chamber 10 could also be varied by varying the pressure in the liquid source 16 but such does not produce a simultaneous change as does varying the stroke or frequency of the stroke of the piston 17. Primary breakdown of the liquid occurs within the mixing chamber 10 after it is metered into the chamber.

As the mixture flows from the mixing chamber 10 through its outlet 19 into the rotating drum 20, the shape of the openings 21 in the drum 20 and the speed at which the drum is rotating create oscillations of an ultrasonic frequency on the mixture to thereby break-

down the stability of the liquid. The particular frequency selected depends on the stability of the liquid and the amount of mixing desired. The greater the flow of the mixture through the openings 21 in the drum 20, the greater the amplitude of the waves; an increase in the amplitude of the waves increases the mixing. Thus, an increase in size of the openings 21 increases the amplitude of the waves and, thereby, increases mixing of the liquid and gas. The mixture of liquid and gas flows from the rotating drum 20 through its outlet 24 into the passage 26 and the open ended tubular member 25. By designing the passage 26 as an exponential flare, as previously set forth, there is a maximum transfer of energy from the resonant chamber to the open ended tubular member 26.

While the mixing device of Fig. 1 may be employed with any pressure differential between the opening 11 in the mixing chamber 10 and the outlet of the open ended tubular member 26, the apparatus of Fig. 2 may be employed only with a specific fixed differential between the gas entering the device under pressure and the mixture leaving the device. In Fig. 2, the gas under pressure enters the resonant chamber 30, which is fixed rather than rotating as in Fig. 1, through an opening or openings 31. The resonant frequency of the chamber 30 depends on the pressure differential so that it is not necessary for the chamber to be movable. The openings 31 are designed to create oscillations of an ultrasonic frequency within the gas. The liquid is metered into the resonant chamber 30 through an opening or openings 32 by the metering device of Fig. 1, identified by the numeral 33 in Fig. 2. The openings 32 are located a quarter of a wavelength from the top of the resonant chamber. This is to insure that the liquid is metered into the resonant chamber 30 through the openings 32 at a pressure node. Since the resonant frequency of the resonant chamber 30 depends upon a pressure differential, which is fixed, the wavelength may be easily determined so that the exact location of the opening or openings 32 may be easily calculated. The resonant chamber 30 communicates with an open ended tubular member 34 through a passage 35. This passage is designed in the shape of an exponential flare so as to match the resonant chamber 30 with the open ended tubular member 34. The length of the tubular member 34 is such that the tubular member 34 is in resonance with the frequency existing within the resonant chamber 30.

Considering the operation of the device of Fig. 2, the gas under pressure flows into the resonant chamber 30 through the opening 31. As it passes through the opening 31, oscillations of ultrasonic frequency are created on the gas. The liquid is metered by the metering device 33 into the resonant chamber 30 through the opening 32. Since the opening 32 is located at a pressure node of the waves being generated within the resonant chamber 30, the liquid enters with a minimum of interference with the oscillations created by the gas passing through the opening 31. These oscillations of the gas tend to breakdown the liquid to thereby produce an optimum distribution of the liquid throughout the gas. The mixture flows from the resonant chamber 30 into the open ended tubular member 34 with a minimum of attenuation due to the passage 35 having an exponential flare.

An advantage of this invention is that the use of the mixing device with fuel and air as the liquid and gas would increase the efficiency of a combustion engine. The use of the mixing device of the present invention with jet engines would reduce the size and length of the burner and thereby reduce the overall engine size resulting in a substantial saving.

For purposes of exemplification, particular embodiments of the invention have been shown and described according to the best present understanding thereof.

However, it will be apparent that changes and modifications in the arrangement and construction of the parts thereof may be resorted to without departing from the true spirit and scope of the invention.

I claim:

1. A device for mixing a liquid and a gas comprising a mixing chamber, means to supply gas under pressure to the mixing chamber, means to introduce a predetermined quantity of liquid into the chamber, a rotating hollow drum connected to the outlet of the chamber and functioning as a resonant chamber, said drum having a plurality of openings in its wall, each of said openings separately communicating with the outlet of the mixing chamber during rotation of the drum to allow intermittent flow of the mixture therethrough into the interior of the hollow drum to create oscillations of the mixture in the ultrasonic range in the interior of the drum, said drum having an outlet in one end thereof, and an open ended tubular member communicating with the outlet of the drum and in resonant frequency with the oscillations in the interior of the drum.

2. A device for mixing a liquid and a gas comprising a mixing chamber, means to supply gas under pressure to the mixing chamber, means to introduce a predetermined quantity of liquid into the mixing chamber, a rotating hollow drum connected to the outlet of the chamber and functioning as a resonant chamber, said drum having a plurality of openings in its wall, each of said openings separately communicating with the outlet of the mixing chamber during rotation of the drum to allow intermittent flow of the mixture therethrough into the interior of the hollow drum to create oscillations of the mixture in the ultrasonic range in the interior of the drum, said drum having an outlet in one end thereof, an open ended tubular member in resonant frequency with the oscillations in the drum, and means including a passage connecting the outlet of the drum with the open ended tubular member, said passage having its cross-sectional area increasing exponentially with distance from the outlet of the drum to the open ended tubular member whereby the mixture flows from the drum to the tubular member with a maximum transfer of energy.

3. A device for mixing a liquid and a gas comprising a mixing chamber, means to supply gas under pressure to the mixing chamber, means to introduce a predetermined quantity of liquid into the mixing chamber, a rotating hollow drum connected to the outlet of the chamber and functioning as a resonant chamber, said drum having a plurality of openings in its wall, each of said openings separately communicating with the outlet of the mixing chamber during rotation of the drum to allow intermittent flow of the mixture therethrough into the interior of the hollow drum to create oscillations of the mixture in the ultrasonic range in the interior of the drum, said drum having an outlet in one end thereof, an open ended tubular member in resonant frequency with the oscillations in the drum, and means including a passage connecting the outlet of the drum with the open ended tubular member, said passage having its cross-sectional area increase with distance from the outlet of the drum to the open ended tubular member and the largest cross-sectional area of the passage having a circumference equal to at least one wavelength of the lowest frequency produced in the drum.

4. A device for mixing a liquid and a gas comprising a mixing chamber, means to supply gas under pressure to the mixing chamber, means to introduce a predetermined quantity of liquid into the mixing chamber, a rotating cylindrical hollow drum connected to the outlet of the mixing chamber and having its axis of rotation substantially perpendicular to the axis of the outlet of the mixing chamber, said drum having a plurality of openings circumferentially disposed in its wall, each of said openings separately communicating with the outlet of the mixing chamber during rotation of the drum to

allow intermittent flow of the mixture therethrough into the interior of the hollow drum to create oscillations of the mixture in the ultrasonic range in the interior of the drum, one end of the drum having an outlet therein for the flow of the mixture therefrom.

5. A device according to claim 4 in which the length of the drum is equal to an odd quarter wavelength of the frequency produced within the interior of the drum.

6. A device for mixing a liquid and a gas comprising a mixing chamber, means to supply gas under pressure to the mixing chamber, means to introduce a predetermined quantity of liquid into the mixing chamber, a rotating cylindrical hollow drum connected to the outlet of the mixing chamber and having its axis of rotation substantially perpendicular to the axis of the outlet of the mixing chamber, said drum having a plurality of openings circumferentially disposed in its wall, each of said openings separately communicating with the outlet of the mixing chamber during rotation of the drum to allow intermittent flow of the mixture therethrough into the interior of the hollow drum to create oscillations of the mixture in the ultrasonic range in the interior of the drum, one end of the drum having an outlet therein for the flow of the mixture therefrom, an open ended tubular member in resonant frequency with the oscillations in the interior of the drum, and means including a passage connecting the outlet of the drum with the open ended tubular member, said passage having its cross sectional area increase exponentially with distance from the outlet of the drum to the open ended tubular member whereby the mixture flows from the drum to the tubular member with a maximum transfer of energy.

7. A device for mixing a liquid and a gas comprising a mixing chamber, means to supply gas under pressure to the mixing chamber, means to introduce a predetermined quantity of liquid into the mixing chamber, a rotating cylindrical hollow drum connected to the outlet of the mixing chamber and having its axis of rotation substantially perpendicular to the axis of the outlet of the mixing chamber, said drum having a plurality of openings circumferentially disposed in its wall, each of said openings separately communicating with the outlet of the mixing chamber during rotation of the drum to allow intermittent flow of the mixture therethrough into the interior of the hollow drum to create oscillations of the mixture in the ultrasonic range in the interior of the drum, one end of the drum having an outlet therein for the flow of the mixture therefrom, an open ended tubular member in resonant frequency with the oscillations in the interior of the drum, means including a passage connecting the outlet of the drum with the open ended tubular member, said passage having its cross-sectional area increase with distance from the outlet of the drum to the open ended tubular member and the largest cross-sectional area of the passage having a circumference equal to at least one wavelength of th lowest frequency produced in the drum.

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