

[54] **LIQUID-SPRAYING DEVICES HAVING A NOZZLE SUBJECTED TO HIGH-FREQUENCY VIBRATIONS**

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[22] Filed: **Mar. 27, 1972**

[21] Appl. No.: **238,201**

[30] **Foreign Application Priority Data**

Apr. 2, 1971 Great Britain..... 8,548/71

[52] U.S. Cl..... **239/102, 239/124, 239/521**

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

[58] Field of Search..... 239/102, 124, 127, 239/521

[56] **References Cited**

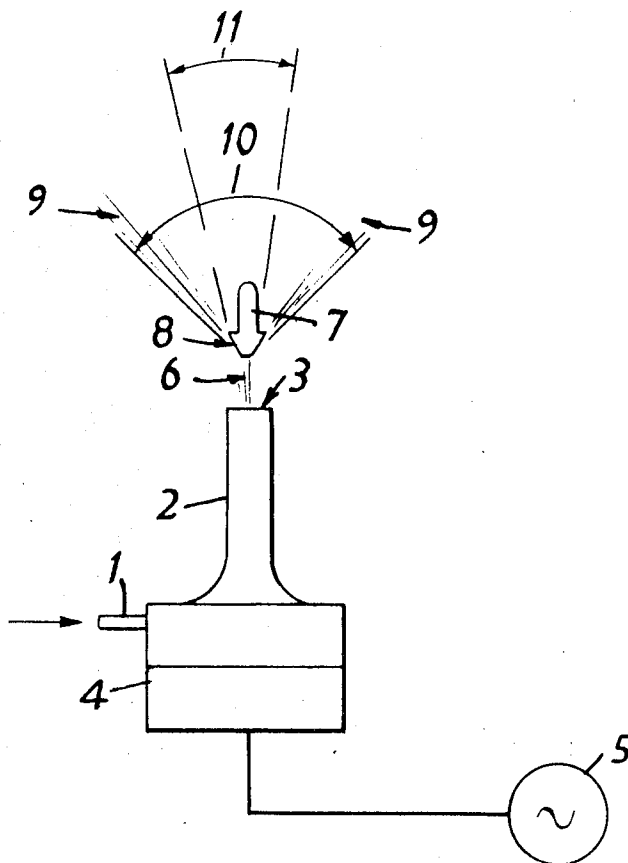
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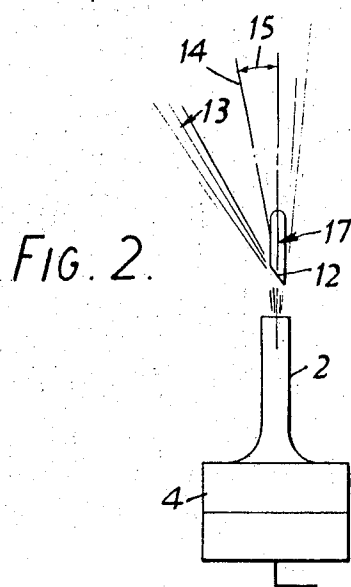
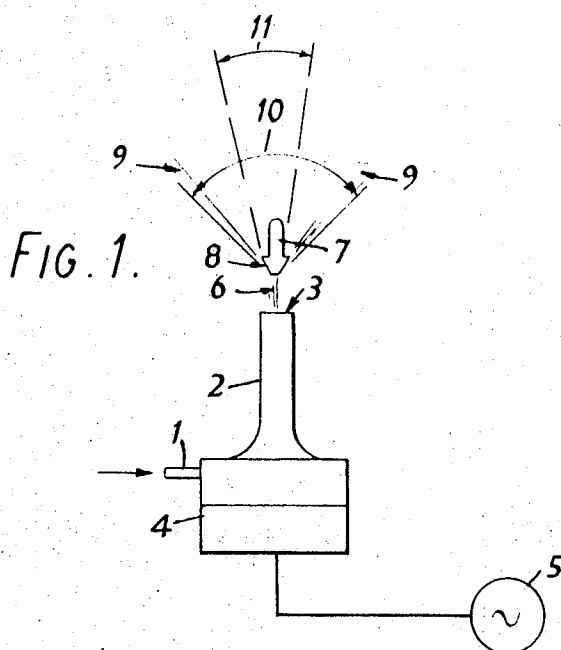
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[57] ABSTRACT

In order to improve the fuel atomization obtained by a stepped-horn type ultrasonic fuel-jet atomizer nozzle, an impact surface body is placed into the path of the fragmented jet ejected from the nozzle. Preferably the impact body is arranged at the inlet end of a collector tube by which the fluid of the jet from the nozzle is withdrawn when the vibrator for the ultrasonic nozzle is not energized, and by its shape and angular displacement relative to the jet axis, the direction and shape of the resultant spray of the droplets can be determined.

4 Claims, 2 Drawing Figures





LIQUID-SPRAYING DEVICES HAVING A NOZZLE SUBJECTED TO HIGH-FREQUENCY VIBRATIONS

This invention relates to the spraying of liquid fuels and other liquids and has for an object to provide improved spraying devices of the kind in which longitudinal vibrations of what will hereinafter be called ultrasonic frequencies are applied to a liquid-emitting jet-forming nozzle in order to break up the jet to form the desired spray. While there would not appear to be a direct relation between the range of frequencies which will ensure a satisfactory break-up of the jet and the frequency corresponding to the upper limit of perception by a normal human ear, the term ultrasonic frequency is nevertheless used in the present specification as meaning a frequency high enough to produce a satisfactory break-up of a liquid jet. This appears justifiable because on the one hand a satisfactory break-up cannot generally be achieved by frequencies very much lower than the maximum frequency perceptible by an average human ear, and more particularly because in practice a frequency above that limit of perception will generally be employed in order to avoid the creation of unnecessary audible noise.

Although it has been found possible to break-up a jet of liquid emitted by a nozzle into a very fine mist by the application to the jet of ultrasonic vibrations in the longitudinal direction of the jet, a satisfactory degree of such break-up has so far been achieved in that manner only at some considerable distance from the nozzle exit. We believe that this is due to the fact that the vibrations in the first instance break up the solid jet into a relatively small number of separate packages, and only subsequently is each of these packages resolved into small droplets by mechanical interaction with the air into which the jet is emitted.

According to the present invention break-up of the jet into a fine mist can be achieved with very much less requirement in air space if the jet-forming nozzle is directed at an impact surface arranged a short distance ahead of the nozzle, for example at a distance of about 6 millimeters. When the vibrator is operated, the vibration of the nozzle will break-up the jet emitted from the nozzle into separate packages, one package being delivered for each cycle of vibration, and as each package impinges upon the impact surface, the package will itself break-up into a fine spray of droplets. If the impact surface is perpendicular to the jet axis, this spray will emerge uniformly round that axis. If on the other hand the impact surface is inclined to the axis of the jet, the spray will emerge at an angle to the jet axis, so that suitable three-dimensional shaping of the impact surface may be employed to break-up the jet into a pre-arranged spray pattern.

The invention is believed to be of particular advantage when used in combination with the invention described in our U.S. Pat. No. 3,613,649 in which a nozzle equipped with an ultrasonic vibrator is arranged to emit continuously a normally solid jet of liquid directed at a collector aperture. This aperture is generally provided at the end of a collector tube, and while normally substantially all the liquid of the jet is withdrawn through this aperture from the air-filled chamber into which the nozzle is directed, when a pulse of ultrasonic-frequency vibrations is applied to the nozzle in its axial direction, the jet is, during the pulse of the vibrations, broken-up into a fine spray which becomes mixed with

the air in the chamber in question. We have found that the effectiveness of this device to form a fine spray is greatly enhanced if the end of the collector tube, or some other surface surrounding the collector aperture, is formed as an impact surface in accordance with the present invention. If this is a plane surface perpendicular to the axis of the jet, it will produce a fine spray of droplets which will emerge at an angle of about 20° to the axis uniformly round the collector aperture.

According to a preferred feature of the invention, at least part of the impact surface is inclined at an angle to a plane normal to the axis of the jet, with the result that the spray produced from any portions of liquid striking such part of the impact surface will emerge from the impact surface at an angle different from the normal 20° angle, so that by suitable shaping of the impact surface within the impact area the spray achieved may be adapted to requirements both as regards its direction and angle and as regards its cross-sectional shape. This may be utilized to direct the produced spray from one chamber through an aperture of the wall thereof into another chamber. Thus if the end of a collector tube, or an impact surface surrounding a collector orifice, facing the nozzle jet, has the shape of a symmetrical wedge whose edge extends diametrically across the axis of the orifice and jet, a spray pattern can be produced which has the appearance of a fan covering an angle of about 90° in a plane normal to the edge of the wedge, while on the other hand if the impact surface is arranged throughout at an angle to the axis of the jet and collector aperture, the spray will be deflected throughout in the direction of inclination by an angle determined by the angle of inclination of this impact surface. Both these forms of the invention have been tried experimentally and no appreciable deterioration in the regularity of the spray droplets was noticed when carrying out these experiments.

In order that the invention may be more readily understood, two embodiments of ultrasonic spray devices incorporating the invention will now be described with reference to the accompanying drawing, in which

FIG. 1 is a somewhat diagrammatic elevation showing an arrangement producing two fan-shaped sprays forming an angle of about 90° with each other, and

FIG. 2 similarly shows an arrangement which produces a single spray deflected to one side of the axis of the collector tube.

Referring now first to FIG. 1, liquid fuel is supplied from a suitable source, 20, to a pipe 1 entering the neutral zone of a piezo-electric vibrator nozzle. This nozzle ends in a sharp-edged orifice 3 and is equipped with a piezo-electric ceramic element 4 arranged for the generation of vibrations in the longitudinal direction of the nozzle when the element is energized, approximately at its resonant frequency, by a source 5 of alternating current of ultrasonic frequency as hereinabove defined. The nozzle is arranged to produce a jet 6 leaving the sharp-edged orifice 3 in the axial direction of the nozzle, and when the piezo-electric element 4 is energized, this jet becomes fragmented. Facing the nozzle in the axial direction is a collector tube 7 arranged to intercept the jet, when the latter is integral in the absence of ultrasonic vibrations, for return to the fuel source 20 along fuel return line 21. The collector tube 7 is formed, at its end facing the nozzle, with a head 8 in the shape of a wedge symmetrical to the axis of the collector tube 7. When the ceramic element 4 is energized to

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produce ultrasonic vibrations, the jet becomes fragmented, and the greater part of the fuel packages formed from the jet will strike the two wedge surfaces of the wedge-shaped head 8. The succession of fuel packages will be transformed on these surfaces into two sprays 9, 9 of fine fuel droplets. Each of these sprays is concentrated over a narrow angle, and the two sprays are spaced from each other symmetrically by a very much larger angle 10 arranged symmetrically to the joint axis of the nozzle 2 and collector tube 7. To show more clearly the effect of the wedge-shaped head body 8, the angle that is covered by the spray of droplets when employing a plain, square-ended collector tube 7 without a head 8 has been indicated at 11.

The arrangement illustrated in FIG. 2 is similar to that of FIG. 1 as far as the operation of the nozzle device 2 and its vibrator 4 are concerned and also as regards the coaxial arrangement of the nozzle and the collector tube, which latter in this embodiment bears the reference number 17. At its end facing the nozzle 2, however, the collector tube 17, instead of being provided with a symmetrical head as shown at 8 in FIG. 1, is cut off along a plane surface 12 inclined to the axis of the collector tube 17 at an acute angle, of such value that, when the vibrator 4 is energized, the fuel packages, on striking the surface 12, will be transformed into a fine spray 13 arranged about an axis 14 which is inclined by an angle 15 from the axis of the collector tube 17.

The arrangements of the present invention, more particularly those described with reference to the accompanying drawing, may be employed in fuel systems for internal-combustion engines, for example in a manner similar to those of the fuel systems respectively described in the above-mentioned U.S. Pat. No. 3,613,649 and in our co-pending U.S. Pat. Application No. 146,642, and in other fuel systems intended for combustion chambers of various types of gas turbines.

What We Claim Is:

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1. A device for forming a spray of liquid in a body of gas, which comprises a nozzle arranged normally to inject, when fed with such liquid, a jet of the liquid into said body of gas, an ultrasonic vibrator connected to the nozzle to produce, when energized, ultrasonic vibration of the nozzle in the direction of the jet to break-up the jet, and an impact surface arranged to face the jet within the body of gas so as to be impinged-upon, when the vibrator is operated, by packages of liquid forming part of the broken-up jet and to further break-up and transform said packages of liquid into a deflected spray.

2. A liquid spraying device as claimed in claim 1 wherein at least part of the impact surface is inclined at an angle to a plane normal to the axis of the jet.

3. A device for forming a spray of liquid fuel in a body of air to produce a fuel-and-air mixture for use in an internal-combustion engine, which comprises a nozzle arranged to normally inject, when fed with liquid fuel, a jet of the liquid fuel into said body of gas, an ultrasonic vibrator connected to the nozzle to produce when energized ultrasonic vibration of the nozzle in the direction of the jet to break-up the jet, and an impact surface arranged to face the jet within the body of gas so as to be impinged-upon, when the vibrator is operated, by packages of liquid fuel forming part of the broken-up jet, and to further break-up and transform said packages of liquid fuel into a deflected spray, and means for continuously feeding the nozzle with liquid fuel, wherein the nozzle is arranged to direct its jet of fuel into a collector aperture leading to a fuel-return line said impact surface being arranged to surround the collector aperture, and wherein the vibrator is arranged to be energized during a fraction only of each revolution of the engine.

4. A device as claimed in claim 3, wherein at least part of the impact surface is inclined at an angle to a plane normal to the axis of the jet of liquid fuel.

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