United States Patent

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[33] **Great Britain**
[31] **32009**

[54] **FUEL INJECTION SYSTEMS FOR INTERNAL-COMBUSTION ENGINES FED WITH A FUEL-AND-AIR MIXTURE**
4 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** ..... **123/119 E,** 123/32 EA, 123/139 AW, 123/139 E, 261/1
[51] **Int. Cl.** **F02m 27/08,** F02b 51/06
[50] **Field of Search** ..... 123/1, 119 E, 32 EA, 32 AE, 139 E, 139 AW, 119, 52 M, 142; 261/1

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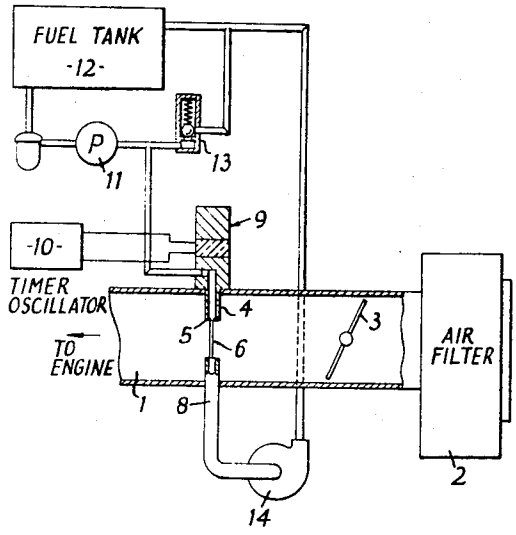
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ABSTRACT: In a fuel injection system for a mixture-aspiring internal-combustion engine, fuel is injected through a nozzle unit equipped with an ultrasonic transducer so that when the transducer is deenergized the nozzle produces a solid jet passing across the induction pipe of the engine into a collector tube through which the fuel returns to the fuel tank, while when the transducer is energized, the jet disintegrates, the fuel being atomized and therefore substantially all admixed to the induced air. The quantity of fuel thus introduced during each stroke or revolution with the airflow in the induction pipe is determined by the length of the energization period of the transducer.



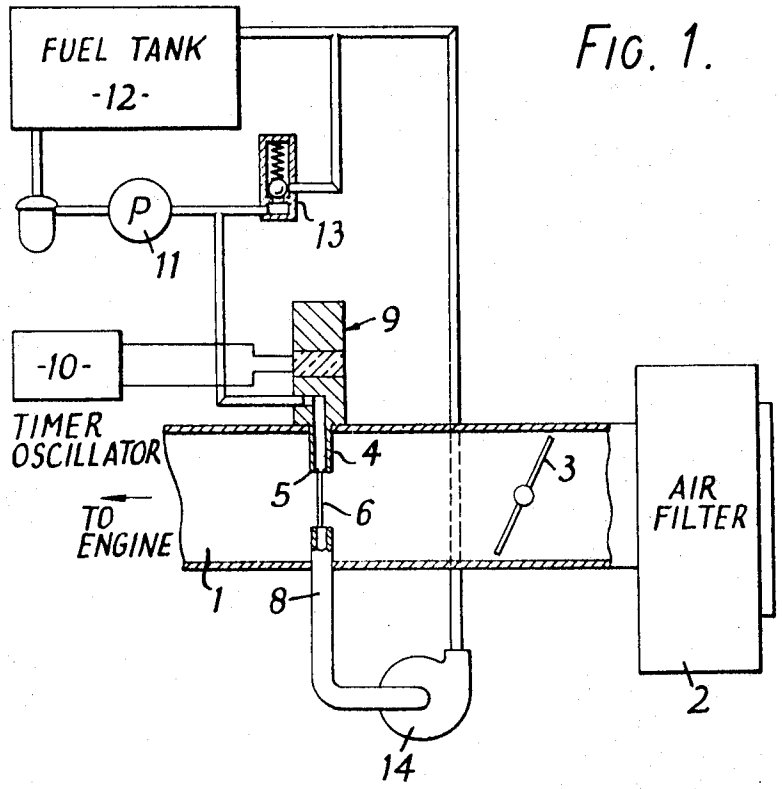
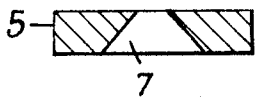

FUEL TANK
-12-
P
11
13
9
-10-
TIMER
OSCILLATOR
TO
ENGINE
4
5
6
3
AIR
FILTER
1
8
2
14

FIG. 1.

FIG. 2.


5
7

FUEL INJECTION SYSTEMS FOR INTERNAL-COMBUSTION ENGINES FED WITH A FUEL-AND-AIR MIXTURE

This invention relates to mixture-aspiring internal-combustion engines and has for an object to provide an improved fuel injection system for an engine of the kind specified which lends itself readily to variation of the quantity of fuel injected during each induction stroke of each cylinder, or each revolution of the engine, and by which an intimate mixture of the injected fuel with the induction air in the form of a mist is achievable.

In British patent specification No. 1,138,536 we have described and claimed a fuel injection system in which an injection nozzle is arranged in the air induction pipe of an internal-combustion engine and fuel is normally maintained in this nozzle at a pressure insufficient in itself to cause the fuel to leave the nozzle, the injection of the fuel into the airstream and the atomization of the fuel being effected by producing ultrasonic vibrations of the nozzle in its longitudinal direction, the quantity of fuel injected per revolution of the engine for example during each induction stroke of each cylinder, being variably determined by varying the period during the revolution, or during the stroke, in which electric current of appropriate frequency is applied to a transducer producing the ultrasonic vibrations. The present invention has for a more specific object to provide an improved system in which the quantity of fuel injected is less affected by variations of the air pressure in the induction pipe.

According to the present invention fuel is continuously supplied under pressure to a nozzle so arranged in an air induction duct leading to the engine as to normally form in the duct a solid jet of fuel aimed at a collector tube which all the fuel in the jet is normally arranged to reach, and from which the collected fuel is drained or withdrawn, the nozzle being equipped with an ultrasonic vibrator which when energized causes the fuel leaving the nozzle to become atomized into a mist, so that, while the ultrasonic vibrations are applied, the major part, and preferably substantially all, of the injected fuel moves with the air in the induction duct into the engine while very little if any fuel is allowed to reach the collector tube, the quantity of fuel thus mixed with the induction air during each induction stroke of each cylinder, or each revolution of the engine, being variably determined by varying the relative length of the period during each stroke or revolution in which ultrasonic vibrations are applied to the nozzle. This is preferably effected by adjustably varying the relative lengths of the period during which electric current of appropriate frequency is applied to a transducer producing these vibrations.

The term "ultrasonic vibrations" and "ultrasonic frequency" are used in this specification, unless the context otherwise requires, to refer to frequencies whose application to a jet-producing nozzle supplied with liquid will cause the jet of liquid to disintegrate into small mistlike particles. This terminology is that generally employed in the art of so-called ultrasonic fuel atomization. The frequency range in question may in practice be found to have its lower limit somewhere near the upper limit of audibility to a normal human ear, and for reasons of noise suppression it is generally preferable in practice to use frequencies high enough to ensure that they will not produce any audible sound.

One fuel system incorporating the invention will now be described with reference to the accompanying drawing, in which

FIG. 1 diagrammatically illustrates the principal elements of the fuel system, and

FIG. 2 is a cross section, drawn to a larger scale, of the jet-forming nozzle plate of that system.

Referring now to the drawing, an internal-combustion engine (not shown) is arranged to aspire air through an air filter 2 and an induction pipe 1, a butterfly throttle valve 3 being interposed at the inlet to the induction pipe. In accordance with the invention the induction pipe 1 is equipped with a jet-forming nozzle unit 4 having an outlet orifice portion in the form of a nozzle plate 5, shown to a larger scale of FIG. 2, which is so constructed and arranged as to normally produce a solid jet 6 of liquid across the induction pipe 1. For this purpose the outlet bore 7 of the nozzle plate may, as illustrated in FIG. 2 be outwardly flared so as to form at the inlet side a sharp edge at which the jet will become detached from the nozzle bore. Arranged in the induction pipe 1 to face the nozzle 4 is a collector tube 8 which has a bore wide enough and so positioned in the induction pipe as to ensure that normally the solid jet 6 formed by the nozzle unit 4 will wholly enter the bore of the collector tube 8. The nozzle unit 4 forms part of an ultrasonic transducer 9 which when electric current of ultrasonic frequency is supplied to it by a timer-oscillator 10, imparts to the nozzle unit 4 ultrasonic vibrations of such frequency, amplitude and direction as to cause the jet 6 to disintegrate into a fine mist which will become intimately mixed with and carried away by the induced airflow in the induction pipe. A pressurizing fuel pump 11 is driven continuously to withdraw fuel from a fuel tank 12 and supply it at a constant pressure, determined by a pressure-limiting valve 13, to the nozzle unit 4, which accordingly will discharge fuel continuously at a predetermined rate. When the transducer 9 is deenergized, the fuel will, as previously described, pass from the nozzle 5 to the collector tube 8 in the form of solid jet 6 and the fuel collected by the tube 8 is returned to the fuel tank 12 by a return pump 14, shown as a centrifugal pump. When however the transducer 9 is energized by current from the timer-oscillator 10, the nozzle is subjected to mechanical vibrations produced by the transducer 9 and these will cause the jet 6 to disintegrate so that substantially all the fuel injected during such periods of energization will be conveyed by the induced air to reach the engine.

Control of the amount of fuel injected during each induction stroke of each piston, or each revolution of the engine, can accordingly be achieved by varying the length of the period in which the transducer 9 is energized during each induction stroke or each revolution of the engine in relation to the total duration of such stroke or revolution in accordance with the quantity of fuel required to be injected during such stroke or revolution. This control may, for example, be effected, by means of an engine-driven distributor-switch device in which a rotary wiper contact cooperates with a contact of a control element whose angular setting is arranged to vary in accordance with controlling data, subsidiary means being preferably provided to normally prevent the length of the injection period during each stroke or revolution from falling below a predetermined minimum. One suitable example of an arrangement for effecting the timing of the application of ultrasonic vibrations has been described in our said British Pat. specification No. 1,138,536 and illustrated in FIG. 2 thereof, in which the illustrated nozzle unit 14 may be replaced by the nozzle arrangement of the present invention.

What we claim is:

1. A fuel injection system for an internal-combustion engine fed with a fuel-and-air mixture with a nozzle for injecting fuel into a flow duct through which air flows to the engine, and with an ultrasonic vibrator associated with the nozzle for producing atomization of the fuel injected by the nozzle, characterized by the combination of a fuel-feed device which maintains a continuous flow of fuel to the nozzle, the nozzle being so constructed as to emit in the absence of ultrasonic vibrations, a solid jet of fuel, a timing control device which limits the energization of the ultrasonic atomizer to uniformly spaced periods each constituting an adjustable part of a cycle related to the revolution of the engine, and the provision, in the flow duct of a collector aperture connected to a fuel-return line and so arranged in the flow duct as to intercept substantially all the fuel coming from the nozzle when said fuel omitted from the nozzle is in the form of a solid jet.

2. A fuel injection system as claimed in claim 1 for a reciprocating piston engine, characterized by a timing device so connected to the engine as to limit energization of the ultrasonic atomizer to an adjustable part of each suction stroke of each cylinder fed by the flow duct.

3. A fuel system as claimed in claim 1 characterized by an automatic adjusting device for the length of said adjustable part.

4. A fuel system as claimed in claim 2 characterized by an automatic adjusting device for the length of said adjustable part.