United States Patent [15] 3,677,236
Moss [45] July 18, 1972

[54] **FUEL-INJECTION DEVICES FOR MIXTURE-ASPIRING INTERNAL-COMBUSTION ENGINES**

[72] Inventor: **Norman Moss**, Ilford, England

[73] Assignee: **The Plessey Company Limited**, Ilford, England

[22] Filed: **Sept. 8, 1970**

[21] Appl. No.: **70,038**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 727,976, May 9, 1968, abandoned.

[52] **U.S. Cl.** ....**123/32 EA,** 123/32 AE, 261/DIG. 48
[51] **Int. Cl.** **F02m 51/06**
[58] **Field of Search** ....123/32 EA, 32 AE; 261/DIG. 48

[56] **References Cited**

UNITED STATES PATENTS

2,949,900	8/1960	Bodine	123/32 EA
3,407,793	10/1968	Lang	123/32 EA
3,272,187	9/1966	Westbrook et al.	123/32 EA
2,855,244	10/1958	Camp	123/32 EA
2,453,595	11/1948	Rosenthall	261/DIG. 48
2,941,519	6/1960	Zechnall et al.	123/32 EA
3,240,191	3/1966	Wallis	123/32 EA
2,981,244	4/1961	Hendrickson	123/32 EA
2,032,211	3/1936	Tice	123/139 AW

Primary Examiner—Laurence M. Goodridge
Assistant Examiner—Cort Flint
Attorney—Scrivener, Parker, Scrivener and Clarke

[57] **ABSTRACT**

To control the rate of fuel injection into the induction pipe of a combustion engine, a transistor switch is arranged to vary the length of each energization of a periodically energized ultrasonic transducer which produces fuel atomization by longitudinally vibrating the open outlet end of a fuel nozzle which leads into the induction pipe and in which the fuel pressure is kept in balance with the air pressure in the induction pipe.

6 Claims, 2 Drawing Figures

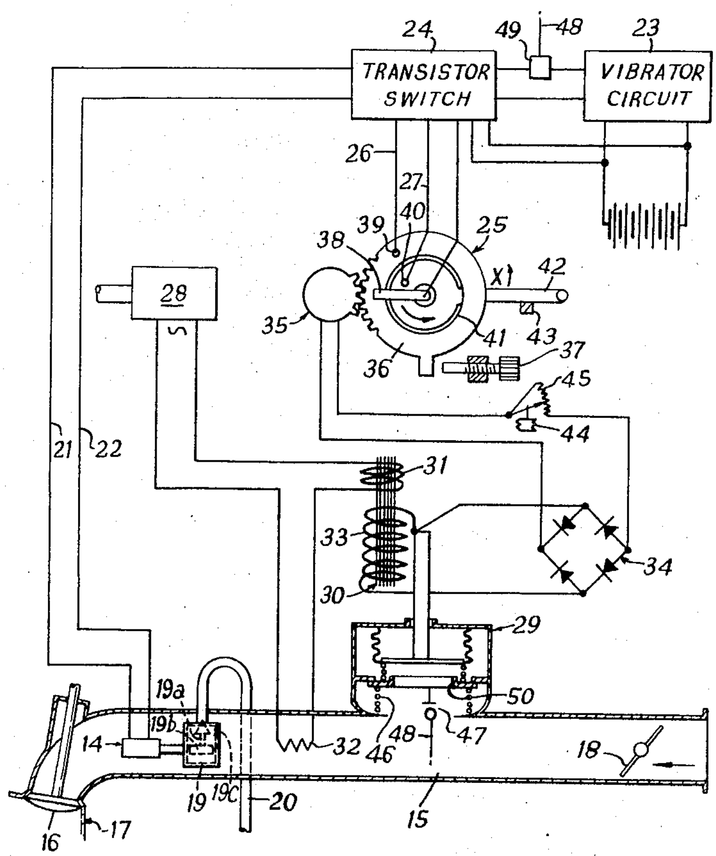
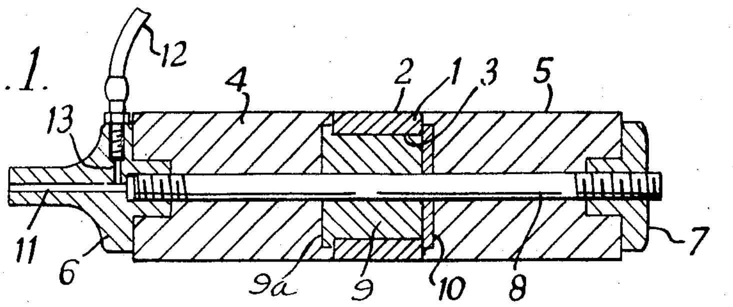


Fig. 1.


12
4
2
1
3
5
13
11
6
9a
9
10
8
7

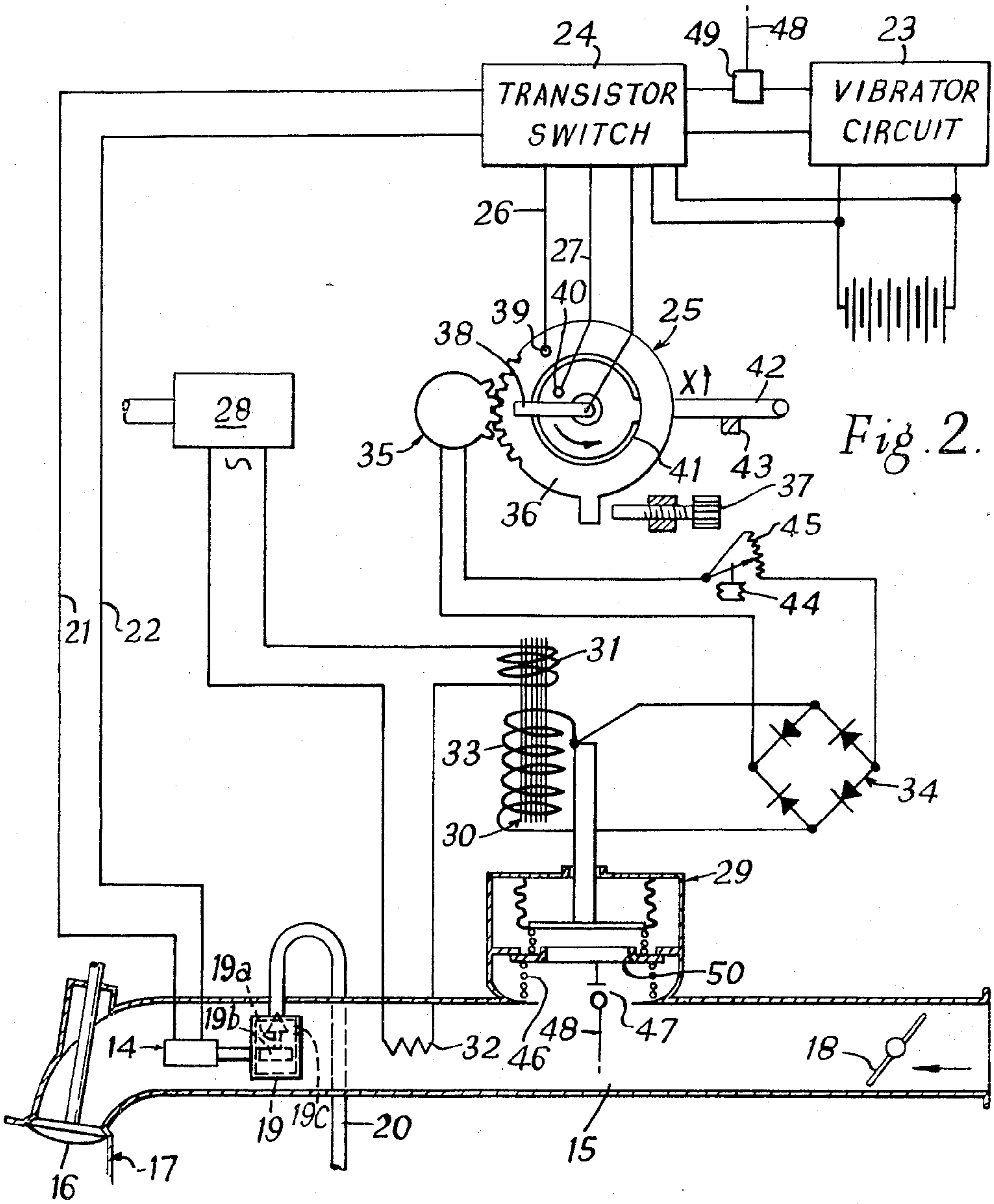

TRANSISTOR SWITCH
VIBRATOR CIRCUIT
24
49
48
23
26
27
39
40
25
38
X
42
28
35
41
43
36
37
45
44
21
22
31
33
34
30
29
19a
50
19b
14
32
46
48
47
18
19
19C
20
15
16
17

Fig. 2.

FUEL-INJECTION DEVICES FOR MIXTURE-ASPIRING INTERNAL-COMBUSTION ENGINES

This application is a continuation-in-part of application, Ser. No. 727,976 filed May 9, 1968, abandoned.

This invention relates to mixture-aspiring internal combustion engines and has for an object to provide an improved fuel-injection system for engines of the kind specified which lends itself readily to variation, independently of the operation of any valves, of the rate of fuel injection, and particularly in a reciprocating engine to variation of the quantity of fuel injected during each induction stroke of each cylinder, in combination with good atomization of the injected fuel.

According to the present invention fuel is injected into the stream of combustion air by means of an open-ended nozzle in which normally fuel is maintained in pressure balance with the pressure in the air stream, the injection of the fuel into the airstream and its atomization being effected by producing, during a variable portion of the induction period, ultrasonic vibrations of the open end of the nozzle in its longitudinal direction, the quantity of fuel injected during, for example, each induction stroke of each cylinder, being controlled by varying the fraction of the period of the stroke or the like in which electric current of appropriate frequency is applied to a transducer to produce the ultrasonic vibrations.

In order that the invention may be more readily understood, one embodiment will now be described in more detail with reference to the accompanying drawings, in which

FIG. 1 is a somewhat diagrammatic axial section of a nozzle unit comprising an ultrasonic transducer and an open-ended fuel-injection nozzle, and

FIG. 2 is a diagram of the layout and electric circuit for a fuel-injection system.

Referring now first to FIG. 1, a suitable form of nozzle unit comprises a piezo-electric transducer element 1, for example of barium-titanate material, in the form of a cylindrical annulus having metallized coatings 2 and 3 respectively applied to its exterior and interior cylinder surfaces so that, when an alternating voltage is applied across the two coatings, the element will alternately contract and expand longitudinally. This longitudinal vibration is transmitted, through aluminum bodies 4 and 5 respectively, to a nozzle body 6 at one end and to a second body 7 at the other end of the device. These two bodies are clamped to the two sides of the transducer element 1 by a stud 8 having screw-threaded ends engaging screw-threaded bores of the nozzle body 6 and of the second body 7 respectively. A bush 9 of insulating material having at one end a flange 9*a* and a washer 10, also of insulating material and placed against the other end of the bush 9, are provided to center the element 1 relative to the aluminum bodies 4 and 5 and prevent these bodies from electrically short-circuiting the inner and outer coatings 2 and 3 of the element 1. The nozzle 6 has an axial bore 11, which is open at its outer end, and to which near its other end fuel is supplied from a flexible connection 12 by a passage 13. It has been found that, when, with the fuel pressure at the nozzle outlet balanced with the pressure of the adjacent air, the nozzle 11 is vibrated longitudinally by the application of a suitable ultrasonic-frequency voltage to the coatings 2 and 3 of the element 1, fuel is emitted from the nozzle in the form of a spray at a rate which, for a given frequency and amplitude of the voltage, is substantially constant, so that the amount of fuel injected is proportionate to the length of time during which the ultrasonic voltage is applied.

Referring now to FIG. 2, which illustrates a convenient manner in which the transducer and nozzle equipment may be arranged in the induction pipe of an engine, the unit described with reference to FIG. 1, bears as a whole unit the reference numeral 14 and is arranged in an induction pipe 15 containing near it inlet end a throttle 18. This induction pipe leads to the inlet manifold and inlet valves 16 of a combustion engine 17, and the unit 14 is fed with fuel from a float chamber 19, which is accommodated in the induction pipe 15 and is fed under the control of a needle valve 19*a* operated by a float 19*b* accommodated in the float chamber 19, from a feed line 20 supplied in the usual manner either under static pressure from a fuel tank or by a suitable low-pressure fuel pump, not shown. The float chamber 19 is vented, above its fuel level, to the interior of the induction pipe 15, so that the pressure acting in the induction pipe at the end of the nozzle 14 also acts on the fuel in the float chamber 19, and the level of fuel in the float chamber is so arranged that the fuel pressure in the nozzle 14 is insufficient to cause any significant amount of fuel to escape from the opening of the nozzle 11 of the unit 14 except during operation of the transducer element 1.

In order to operate the transducer element, a voltage of ultrasonic frequency is supplied to it by leads 21 and 22 from a vibrator circuit 23 under the control of a transistor switch 24. The latter is controlled by a differential distributor 25, in which an engine-driven wiper arm 38 co-operates with a control-ring element 36 and an inner ring 41 to periodically energize an ON-line 26 to close the transistor switch 24 and subsequently to energize an OFF-line to open the transistor switch. In the case of a four-stroke engine this closing of the transistor switch is effected shortly after the beginning of each induction stroke, and the OFF-line 27 is energized at a later time of the induction stroke. Both times are variable by signals in a manner which will now be discussed in more detail.

One of the signals employed for this purpose is arranged to be produced by an alternating-current generator 28 of the permanent-magnet type. This generator is driven by the engine and produces a voltage proportional to the engine speed. Another signal is produced by a manifold-pressure transducer 29, which alters the transmission ratio or multiplication factor of a variable transformer 30 by varying the number of operative turns in the secondary transformer winding 33. The primary winding 31 of the transducer 30 is supplied with the voltage output of the engine-driven generator 28 via a resistor 32 whose resistivity varies substantially with its temperature, and which is arranged in the induction pipe 15. The output of the transformer secondary 33 is, after rectification in a rectifier bridge 34, applied to a torque motor 35 which is so arranged that it will take up an angle of deflection proportionate to its input voltage, and which determines the angle setting of the ring element 36 of the differential distributor 25 in such manner as to increase the length of the injection period relative to the total period of each input stroke with rising engine speed and with rising pressure in the induction line. An adjustable idling-setting stop 37 has been additionally provided to prevent the length of the fraction of the input stroke utilized for injection from falling below a predetermined minimum.

The triggering of the ON-line 26 and the OFF-line 27 is effected by co-operation of the engine-driven wiper arm 38, which, in the case of a four-stroke engine, rotates at half the engine speed, with an ON-line contact 39 arranged on the adjustable control-ring element 36, while an OFF-line contact 40 is arranged on the normally fixed inner ring 41. Since in practice the inlet-pressure transducer 29 measures the excess pressure in the induction pipe over ambient pressure rather than the absolute pressure, a correction of the signal in accordance with the ambient pressure is required, more particularly in order to compensate for varying altitude, and for this purpose an altitude-control resistor 45 is included in the energizing circuit of the torque motor 35. This resistor may be operated by an aneroid capsule 44, although, since this control is not particularly critical, manual altitude control might be substituted. In order to facilitate starting in cold weather, the inner ring 41 is adapted to be manually turned by a choke lever 42 by a certain angle in the direction of the arrow X from its normal position determined by a stop 43.

With the arrangement as so far described a minimum amount of fuel corresponding to idling at the actual speed of the engine will be supplied even when the throttle is closed at high engine speed, whereas in such conditions, for example when coasting down a hill, it is really desirable that fuel should not be supplied at all or at least its supply to be cut to a minimum. For this reason a stop 50, which normally limits the movement of the pressure-transducer 29 at low induction-line pressure, is allowed to yield when the suction exceeds a predetermined value. This is achieved by the provision of a trapped pre-loaded spring **46**, so that when the suction exceeds that predetermined value, the pressure transducer will move below the normal minimum position, thus causing the ring **36** to move beyond the normal minimum position for the actual speed of the engine to the position defined by the stop **37**. If desire, compression of the pre-loaded spring **46** may alternatively be employed to switch off the vibrator circuit altogether, for example by a switch contact **47** in a line **48** leading to an auxiliary transistor switch **49** in the output of the vibrator circuit **23**.

It will be readily appreciated that while a magnetostrictive transducer has been described and illustrated, the system of the invention is not limited to the use of this kind of transducer, which may for example be replaced by an electromagnetic transducer.

A further auxiliary switch, controlled for example by the output voltage of alternator **28**, is preferably included in the output of the vibrator circuit to prevent the injection of fuel until the engine speed reaches a predetermined value lower than the idling speed.

Furthermore while in the illustrated embodiment the nozzle **14** and float chamber **19** are shown in the induction pipe **15** at a point beyond the throttle **18**, this arrangement may be modified by arranging the float chamber **19** outside the induction pipe so long as its vent aperture **19*c*** is arranged to communicate with the appropriate part of the induction pipe **15**, and if desired the injection nozzle **14** may be arranged in the entry portion of the induction pipe **15** preceding the position of the throttle **18**, i.e. at a point where pressure variations from the outside atmosphere are relatively small.

What I claim is:

1. A valveless device for injecting liquid fuel into an air-induction line conveying a flow of combustion air to a mixture-aspiring combustion engine, comprising a low-resistance injection nozzle having an open-ended outlet portion leading into the air-induction line, means for supplying liquid fuel to said nozzle and for automatically maintaining the fuel pressure in the open end of said outlet in balance with the pressure of the adjacent air, an ultrasonic transducer which when energized produces ultrasonic vibrations of the outlet portion of the nozzle in its longitudinal direction to atomize and inject fuel from said nozzle into the flow of combustion air in the air-induction line, first control means for periodically initiating energization of said transducer, further control means associated therewith, for terminating each period of such energization, and automatic means for variably controlling the length of each such period in accordance with operating data of the engine.

2. A fuel-injection device as claimed in claim **1** for a reciprocating-piston engine, wherein said first control means are arranged to operate near the commencement of each induction stroke of each cylinder, and wherein said further control means are arranged to operate at a later point of said stroke whose cyclic spacing from said first point is arranged to vary in proportion to the product of engine speed and the amount of fuel required per induction stroke.

3. A fuel-injection device as claimed in claim **2**, wherein the means for variably determining the period of energization of the transducer comprise an engine-driven distributor-switch device in which a rotary-contact wiper co-operates with a control contact whose angular setting is arranged to vary in proportion to the engine speed and to a function of induction-line pressure to determine one of the terminal points of the transducer-energization period, subsidiary means being provided which normally prevent the length of the energization period from falling below a predetermined minimum.

4. A device as claimed in claim **3**, wherein an element arranged to co-operate with the wiper to determine the other of said terminal points, is adjustable from a normal position in a direction opposite to the displacement of the control element from said minimum position.

5. A device as claimed in claim **1**, which includes an automatic device preventing operation of the transducer until the engine speed reaches a predetermined value.

6. A device as claimed in claim **1**, which includes means operable to increase the length of each energization period of the transducer in order to facilitate the starting of the engine from a cold condition.

* * * * *