United States Patent [19]

Broad et al.

[11] **3,746,257**

[45] **July 17, 1973**

[54] **FUEL-INJECTION SYSTEMS, MORE PARTICULARLY FOR LIQUID-FUEL BURNERS**

[75] Inventors: **Michael John Broad**, Enfield, Middlesex; **Norman Moss**, Ilford, Essex, both of England

[73] Assignee: **Plessey Handel Und Investments A.G.**, Zug, Switzerland

[22] Filed: **June 21, 1971**

[21] Appl. No.: **155,092**

[52] **U.S. Cl.** **239/102**

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

[58] **Field of Search** 239/101, 102, 398

[56] **References Cited**

UNITED STATES PATENTS

2,481,620	9/1949	Rosenthal	239/102
3,064,619	11/1962	Fortman	239/102
3,145,931	8/1964	Cleall	239/102
3,275,059	9/1966	McCullough	239/102 X
3,326,467	6/1967	Fortman	239/102

FOREIGN PATENTS OR APPLICATIONS

1,210,699	10/1970	Great Britain	239/102
752,746	2/1967	Canada	239/102

Primary Examiner—Lloyd L. King

Attorney—Alex Friedman, Harold I. Kaplan et al.

[57] **ABSTRACT**

In order to obtain at low fuel-supply rates the benefit of ultrasonic atomisation assistance in the case of a swirl-type atomiser nozzle, the small-diameter horn of an ultrasonic vibrator extends axially through the swirl chamber of a swirl atomiser into close vicinity of the final outlet orifice of the conical end portion of the chamber so that the active tip of the horn can atomise the fuel as the fuel passes through the orifice while the horn is cleared by the hollow core of the swirl when the fuel-supply rate is sufficeint to ensure swirl atomisation. A pressure-sensitive switch then preferably cuts off the energisation of the oscillator for the ultrasonic transducer. A change-over valve controlled by the pressure-sensitive switch may be employed for diverting at low flow rates the fuel flow so that instead of entering the swirl chamber the fuel flows through an axial bore of the atomiser horn.

4 Claims, 3 Drawing Figures

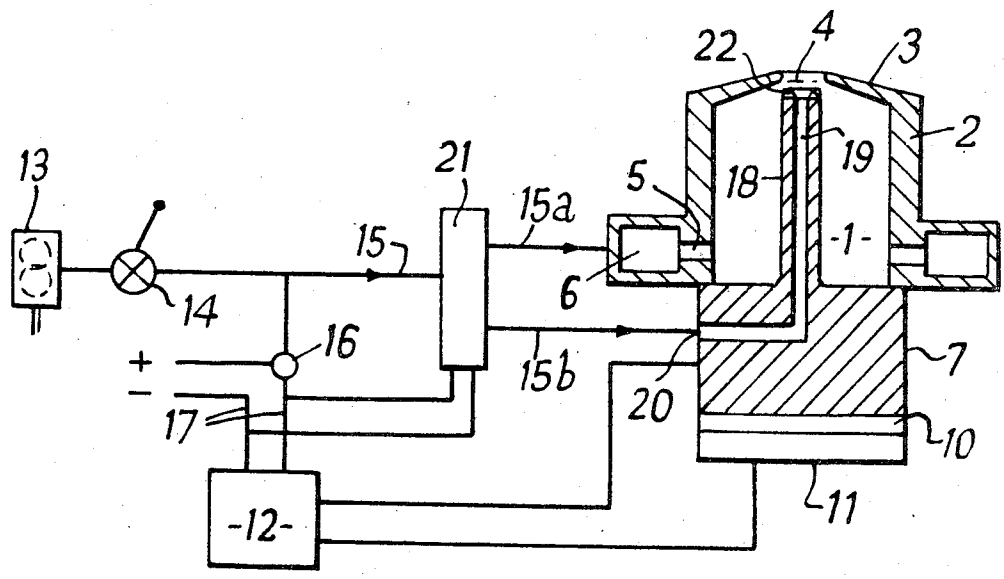


FIG. 1

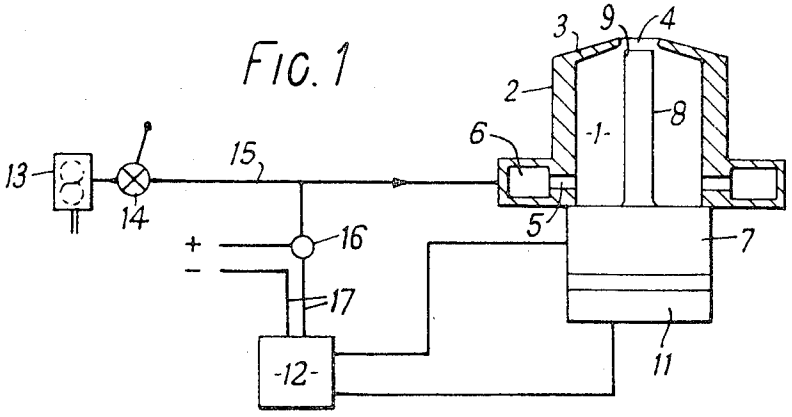


FIG. 2

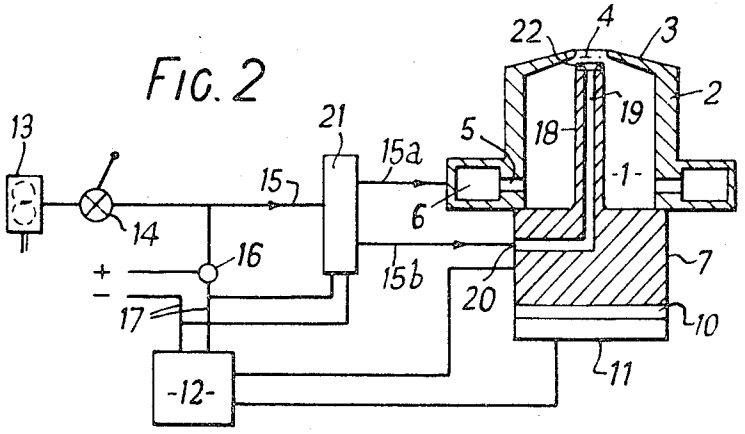
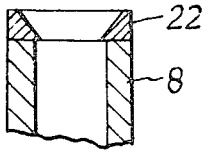


FIG. 3



FUEL-INJECTION SYSTEMS, MORE PARTICULARLY FOR LIQUID-FUEL BURNERS

This invention relates to liquid-fuel injection systems, more particularly for liquid-fuel burners or gas turbines wherein a fuel-injection nozzle dimensioned to ensure adequate pressure atomisation under normal full-load conditions, is formed as part of an ultrasonic atomiser so as to permit this ultrasonic atomiser to be operated to produce high-frequency vibration of the nozzle in the direction of the nozzle axis to assist atomisation when the rate of fuel supply is insufficient to produce satisfactory pressure atomisation.

The present invention has for an object to provide an improved system of the kind specified in which the fuel-injection nozzle is a so-called swirl-type atomiser having a cylindrical swirl chamber into which the fuel from a pressurised supply is admitted tangentially and which at one end tapers to form a central outlet orifice of smaller diameter. Pressure atomisation is effected in such nozzles by utilisation of the rapid swirl movement which occurs when the large-diameter swirling flow produced in the swirl chamber by the tangential inlets is reduced in diameter to that of the outlet orifice. In order to ensure effective atomisation, the rate of fuel admission through the tangential inlets to the swirl chamber must be sufficient to achieve the necessary high rate of swirl in the outlet, so that at lower rates of fuel consumption and correspondingly reduced velocity of the entering fuel, the fuel is liable to leave the nozzle in a so-called tulip formation, rather than in a spray of fine droplets, and at still lower rates of admission the fuel is liable to leave the nozzle as a more or less axial jet.

According to the present invention an ultrasonic vibrator element having a small-diameter horn whose end face has a diameter similar to, or preferably smaller than, the diameter of the outlet orifice, is arranged to extend through the swirl chamber coaxially with the nozzle with the active tip of the horn arranged in the region of the orifice. Preferably the ultrasonic vibrator is a stepped-diameter amplifier of which the large-diameter end is connected to a piezoelectric element or other ultrasonic vibrator, while the reduced-diameter portion or horn of the vibrator extends from the opposite surface of the large-diameter portion in the axial direction of the chamber, its active tip being located in the region of the nozzle orifice, while the nodal face of the ultrasonic atomiser closes the swirl chamber at its end remote from the nozzle orifice. A further object of the invention is to povide a combined swirl-type and ultrasonic atomizer device in which the ultrasonic atomizer means, while effective to ensure atomization at relatively low rates of liquid supply, at which the atomization achieved by swirl action is insufficient to ensure droplet atomization, will cause minimum interference with the swirl-action atomization at higher rates of liqid supply at which the atomization by swirl action is adequate without the assistance of ultrasonic vibrations. With this object in view the ultrasonic vibrator is so arranged that at high flow rates, when the nozzle operates effectively as a swirl atomiser, the ultrasonic vibrator element lies in the hollow core of the circulating flow so as not to interfere with the swirl action of the latter. This makes it possible to cause the ultrasonic vibrator to be de-energised if desired, for example by the action of a pressure switch, when the rate of fuel supply is sufficient to maintain effective swirl atomisation, while when the flow rate is lower, the diameter of the hollow swirl core is also reduced so that the flow will make contact with the end of the vibrator horn, enabling the end of the horn to transmit its ultrasonic vibrations to the fuel passing through the orifice, thus ensuring its atomisation independently of the swirl-atomising action.

By way of a modification, the horn of the ultrasonic vibrator may be provided with an axial bore leading to an outlet orifice in the active end face of the horn, and at low rates of fuel supply the fuel is caused to enter this axial bore via a radial passage near the nodal zone of the vibrator. Effective ultrasonic atomisation of the fuel supplied is thus ensured without having to reply on a radially inward fuel flow component in the nozzle of the swirl chamber to place the fuel into contact with the active tip of the horn.

Two embodiments of the invention will now be described in more detail with reference to the accompanying drawings, in which

FIG. 1 is a somewhat diagrammatic view of a liquid-fuel injection system embodying one form of the invention, the swirl chamber and nozzle being shown in axial section,

FIG. 2 is a similar view of a modified system, and

FIG. 3 is a fragmentary sectional elevation of the active tip portion of the vibrator horn of the embodiment illustrated at FIG. 2.

In the system illustrated by FIG. 1, the swirl atomiser has a body containing a swirl chamber 1 enclosed by a cylindrical circumferential wall 2, which is joined at the outlet end of the chamber by a conical wall portion 3 which tapers from the cylindrical wall 2 to a smaller-diameter outlet orifice having a throat 4. Adjacent to the opposite end of the swirl chamber 1, a number of tangential ports 5 for the admission of liquid fuel to this chamber extend through the wall portion 2 from a gallery 6 surrounding the ported portion of the cylindrical wall 2, and the chamber 1 is closed at its inlet end, beyond the ports 5, by the large-diameter portion 7 of a stepped ultrasonic vibrator, which has a small-diameter stem or horn 8 extending axially through the chamber 1. The active tip 9 of this horn is arranged within the chamber 1, just short of the outlet orifice throat 4. Attached to the oppositely facing surface of the large-diameter portion 7 of the vibrator is a piezoelectric element 10 the opposite side of which is arranged to act on a suitable balance member 11, which is electrically connected to an ultrasonic electric oscillator 12 operating at the resonant frequency of the vibrator 7, 8. A pump 13 supplies fuel to the gallery 6 via a fuel-control valve 14, and the pressure in the line 15 conducting the fuel from the valve 14 to the gallery 6 is communicated to a pressure switch 16 in power lines 17 adapted to be connected to an electrical power supply and leading to the oscillator 12.

When fuel is admitted by the valve 14 at low rates of flow, the pressure switch 16 is closed so that the ultrasonic vibrator is energised at its resonant frequency with a high-frequency alternating voltage. Although the fuel is introduced into the swirl chamber via the tangential inlets 5, its energy is insufficient to establish a vortex within the swirl chamber, and the flow is therefore essentially axial. When the fuel reaches the region of the orifice 4, it makes contact with the vibrating tip 9 of the stem or horn 8 of the ultrasonic vibrator, so

that ultrasonic vibration of the vibrator will break-up the fuel into droplets and cause these to be ejected via the orifice **4**. When the flow rate of the fuel into the swirl chamber is increased, the increased fuel pressure will make sufficient energy available to establish some low-energy vortex in the swirl chamber **1**. In the absence of an ultrasonic atomiser, such vortex would result in the production of a so-called tulip-type flow from the orifice **4**, a flow which gives only poor atomisation. The pressure switch is therefore so constructed that the pressure developed in these circumstances is still insufficient to open the pressure switch **16**, so that the piezoelectric element **10** remains energised with high-frequency electric power, and as a result the vibrating tip **9** of the vibrator horn **8** will add atomising energy to the liquid fuel as it enters the outlet orifice **13**, thus causing the tulip to fragment and good atomisation to be ensured.

When the fuel-flow rate, and accordingly the pressure, is still further increased, the energy of the incoming fuel fed through the tangential ports **5** will eventually become sufficient to produce a high-energy vortex within the swirl chamber **1**, and the fuel emitted from the orifice **4** will in that case be effectively atomised by the swirl action of the fuel so that the operation of the vibrator horn **8** is not required under these circumstances. At the same time the vortex within the swirl chamber **1** will form a hollow core of sufficient diameter to clear the ultrasonic vibrator horn **8**, and the high pressure of the fuel in line **15** occurring in this case will open the pressure-sensitive switch **16** and thus cut-off the energisation of the oscillator by the electrical supply lines **17**.

In the modified embodiment illustrated in FIG. **2** those parts which are identical with those illustrated in FIG. **1** have been given the same reference numerals, and only the altered parts will be described. The horn of the ultrasonic atomiser, which has been given the reference number **18**, has an axial bore **19** which communicates with a radial bore **20** in the large-diameter portion **7** of the atomiser. The fuel-supply line **15** coming from the fuel control valve **14**, which in FIG. **1** leads direct to the gallery **6**, leads in this embodiment to a change-over valve **21**, which is so controlled by the pressure switch **16** that it will admit fuel to a line **15*a*** leading to the gallery **6** only when the pressure switch **16** is open, while when pressure switch **16** is closed, that is to say at low fuel pressures, the change-over valve **21** is moved to a position in which it diverts the flow from line **15** to an alternative line **15*b*** which leads via the radial bore **20** to the axial bore **19** of the ultrasonic horn **18**.

Under such low-pressure conditions accordingly all the fuel is supplied through the axial bore **19** to the active tip **22** of the horn **18** so that in this case all the fuel is subjected to the action of the ultrasonic vibrations of the horn. Preferably the outlet of the axial bore **19** at the active tip of the atomiser horn **18** is formed as a sharp-edged orifice **22** as shown in the larger-scale sectional elevation of FIG. **3**.

What we claim is:

1. An atomizing device for liquid fuel and other liquids, which comprises: a body containing a swirl chamber of circular cross-section, a liquid-inlet passage leading tangentially into said chamber, and a nozzle outlet that extends axially from said chamber and has a throat whose diamter is smaller than that of the swirl chamber; means for supplying liquid to said inlet passage at a rate which is variable between an upper range in which the energy of the liquid entering the chamber through said inlet passage is sufficient to form in said chamber a vortex that produces at the nozzle exit effective swirl atomization of the liquid leaving the chamber through the nozzle and has an internal cavity of predetermined minimum dimensions, and a lower range in which the energy of the liquid entering the swirl chamber is insufficient to form such atomization producing such vortex, an ultrasonic vibrator having a stem terminating in a tip, the vibrator being so connected to said body that said stem extends in the swirl chamber along the axis thereof, the tip of the stem body located within the internal cavity of the vortex formed when the rate of liquid supply is in said upper range, said tip being located approximately in the plane of the said throat, and the vibrator being operative when energised to vibrate the said tip in the longitudinal direction of the stem.

2. A device as claimed in claim **1**, wherein the vibrator stem terminates short of the throat of the nozzle outlet.

3. A device as claimed in claim **1**, which includes a pressure-responsive switch subject to the pressure of the liquid supplied to said inlet passage and operative to cut-off energisation of the vibrator when the said pressure is sufficient to supply liquid at a rate within said upper range.

4. A device as claimed in claim **1** wherein the vibrator stem has a longitudinal bore leading to an orifice at the tip of the stem, and wherein the device includes a pressure-responsive change-over switch subject to the pressure of the liquid supplied by said liquid-supplying means and operative to divert the liquid supplied so as to admit it to said bore instead of admitting it to the swirl chamber when the said pressure is insufficient to supply liquid to said chamber at a rate within said upper range.

* * * * *