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(54) Delivery of fuel to working chambers of internal combustion engines.

(57) Liquid fuel from a controlled supply is delivered to a delivery tube (147) under a pressure which is too low to deliver a charge of fuel under static conditions. During an induction stroke however, air entering a cylinder of an engine is drawn through a venturi-type constriction (156) and thereby draws air from a duct (154) by-passing the engine throttle. This air is drawn through a convergent passage to pass the delivery end of the tube (147) at supersonic velocity to draw therefrom a charge of fuel. The tubes (147) for each inlet passage are in permanent communication with the same metered supply so each cylinder draws its appropriate charge in turn.

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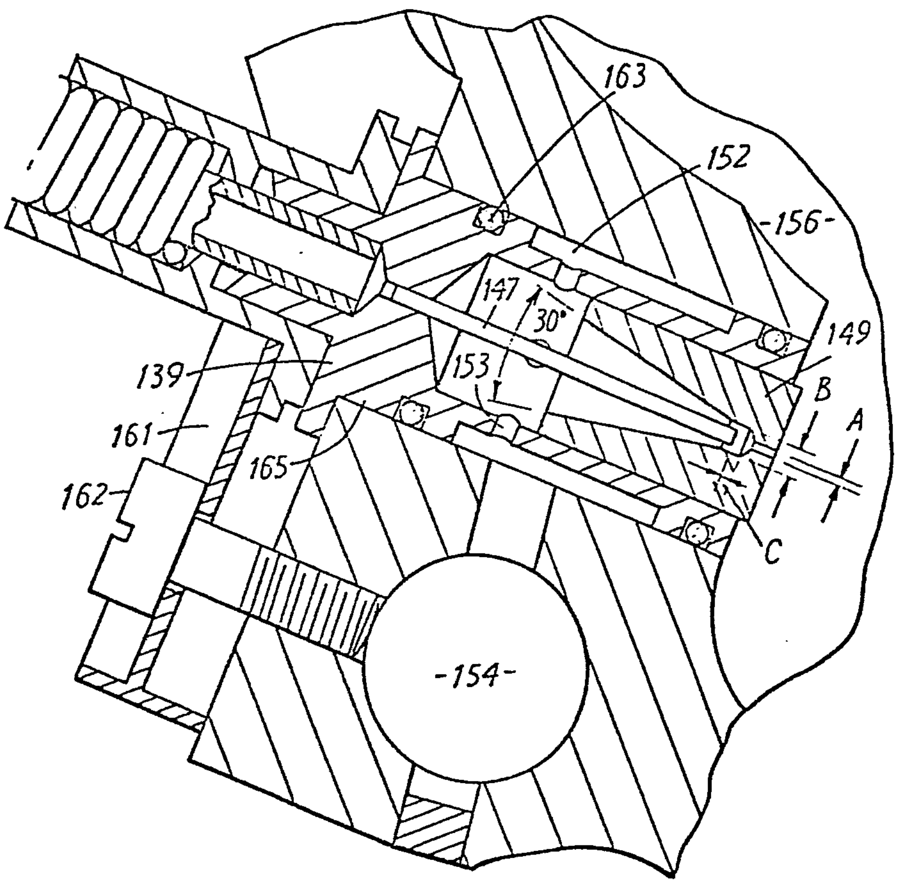


FIG.4

DELIVERY OF FUEL TO WORKING CHAMBERS OF INTERNAL COMBUSTION ENGINES

This invention relates to apparatus for delivering charges of fuel to working chambers of internal combustion engines.

More specifically, the invention is concerned with apparatus for delivering successive charges of fuel to a working chamber of an internal combustion engine from a liquid fuel supply line the flow rate to which is controlled in accordance with operating conditions of the engine, comprising a nozzle mounted in the side wall of an inlet duct leading to the working chamber, the nozzle comprising a small bore fuel delivery tube connected to the supply line and mounted in an air passage connected to receive air from a supply by passing the engine throttle, the air passage being convergent to an outlet for delivering fuel and air into the inlet duct.

Such apparatus is described in GB 1,266,851 and GB 1,330,181 in which the flow rate from the supply line is controlled by the length of pulses fed to solenoid-operated valves which periodically and simultaneously open and close the inlets to the fuel delivery tubes, which in turn discharge fuel into the inlet manifold.

Apparatus according to the invention is characterised in that the delivery tube is continuously connected to the supply line and in that the pressure maintained in the supply line in relation to the dimensions of the delivery tube is insufficient to discharge a charge of fuel from the delivery tube in the absence of air movement in the air passage so that a charge of fuel is delivered by the delivery tube only during induction of a charge of air into the combustion chamber.

Thus, preferably, for liquid fuel, the nozzle has a capillary fuel delivery tube within an air passage connected to receive unthrottled air, the air passage being convergent around the outlet end of the fuel delivery tube and leading to an outlet in a wall of the inlet passage to the working chamber in a position where each successive charge of air drawn into the combustion chamber will reduce the static pressure and thus draw in air from the nozzle air passage. This in turn reduces the static pressure at the fuel delivery tube outlet and draws off and atomises fuel from the tube. At other stages in the engine cycle, the surface tension of the fuel prevents any substantial flow of fuel Where the fuel is supplied under pressure, this should be insufficient to overcome the surface tension when air is not being drawn past the nozzle.

Preferably, the passage around the tube is gradually convergent over a sufficient length to ensure that the velocity of the air drawn past the end of the tube is effectively supersonic under all running conditions, thereby avoiding sudden charges and instabilities in the operation of the nozzle.

Advantageously, the air inlet duct leading from the throttle towards the combustion chamber is formed with a constriction to reduce the static pressure adjacent the nozzle. This constriction should however not be so narrow as to cause sonic flow conditions under maximum power or engine speed conditions. Accordingly, the constriction design should ensure that the mean flow velocity during intake of a charge of air should not appreciably exceed 125 metres/sec.

When the engine has a plurality of working chambers, the fuel delivery apparatus will have a separate nozzle for each air inlet duct (which may serve one or more working chambers), the remainder of the fuel delivery apparatus being common to all nozzles which are effectively connected in parallel. With the usual phase differences between the various working chambers, each nozzle in turn will be caused to deliver fuel as a charge of air is drawn through its associated air inlet passage during the induction phase, thereby helping to ensure that fuel cannot escape from the other nozzles.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which :-

Figure 1 shows diagrammatically the air and fuel delivery systems of a four stroke spark-ignition internal combustion engine;

Figure 2 shows a fuel delivery nozzle of Figure 1 on an enlarged scale; and

Figures 3 and 4 are views corresponding to Figures 1 and 2 of a modified system.

Figure 1 shows a portion of the cylinder head 1 of an internal combustion engine. During an induction stroke, air is drawn in from the atmosphere through a conventional air filter assembly 2 into an induction pipe 3 past a butterfly throttle 4 and into an inlet manifold 5. The air is drawn through the appropriate branch of the manifold 5 into an intake passage 6 in the cylinder head 1 and thence through a valve seat 7 (controlled by a poppet valve, not shown) into the combustion chamber 8. During all other stages of the operating cycle, the valve seat 7 is closed by the poppet valve and no air flow will occur in the passage 6.

Liquid fuel for the engine is stored in a tank 11. Fuel is drawn from the tank 11 by an electrically driven pump 12 and is delivered to a line 13 the pressure in which is maintained at about eighteen pounds per square inch by a relief valve 14 which spills excess fuel back into the tank 11 through a spill line 15.

The line 13 leads to a solenoid operated valve 15 and a variable-orifice valve 16 which are connected in series in either order by a line 17. An electronic control unit 18 receives signals from an engine driven tachometer 19 and delivers to the solenoid 20 of the valve 15 pulses of normally constant length, at a frequency proportional to the engine speed registered by the tachometer 19. Typically, each pulse has a duration in the range 3-10 milliseconds and the valve 15 is effectively fully opened during this period.

The metering valve 16 defines a variable area constriction 22 which is defined conveniently by the registering areas of a slot 23 and a triangular opening 24 in two adjacent relatively movable members. In this embodiment, the member 25 formed with the triangular slot 24 is interconnected through a linkage 26 with the throttle 4 in such a manner that opening movement of the throttle 4 (hereby an accelerator pedal 27 and linkage 28) causes the member 25 to move downwards relative to the slot 23 so that the width, and thus flow area, of the orifice 22 is increased.

By suitable choice of the characteristics of the linkage 26 (which may for example include a non-linear cam) and by appropriate shaping of the opening 24, the required characteristics can be obtained. In general, the resistance to flow of the opening 22 should be similar to that of the appropriate jet or jets of a conventional carburettor which would be used with the engine.

Fuel which has passed through the valves 15 and 16 is delivered through a line 29 to an accumulator and distributor valve assembly 30. The fuel from the line 29 is supplied to the interior of a tubular valve seat 31 against which bears the underside of a diaphragm 32 under the pressure of a compression spring 33, the tension of which can be adjusted by means of a screw 34 with lock nut 35.

The tension in the spring 33 is adjusted so as to arrange that the pressure in an annular outlet chamber 36 and in the line 29 is normally about eight pounds per square inch.

The outlet chamber 36 is permanently connected by outlet ports 37 to lines 38 leading to fuel delivery nozzles 39, there being one such nozzle 39 for each inlet passage 6.

As shown in Figure 2, each nozzle 39 has a hollow body 41 mounted in a bore 42 in the inlet manifold 5 by means of screw threads 43. At its discharge end, an O-ring 44 is located in a groove 45 to form a seal against the wall of the bore 42.

A ferrule 46 is engaged in the hollow body 41 and connected to the line 38. A long capillary tube 47 is engaged in the ferrule 46 and has its outlet end 48 adjacent an outlet orifice 50 in an orifice member 49 which is pressed into the interior of the body 41 and has a frusto-conical surface 51 converging towards the orifice 50.

An annular air space 52 surrounds a reduced portion of the body 41 and communicates with the interior of the body 41 through holes 53 and with an air supply duct 54 by way of a short passage 55. The duct 54 is connected to receive air from the outlet of the air filter 2 upstream of the throttle 4.

Adjacent the nozzle 39, the inlet manifold 5 is formed with a venturi-like constriction 56 the effect of which is to reduce the static component of pressure adjacent the nozzle outlet orifice 50 when a charge of air is being drawn into the combustion chamber 8. This pressure reduction, coupled with the pressure reduction created by the throttle 4 and inlet manifold 5 draws air from the duct 54 into the interior of the nozzle body 41 and through the space between the capillary tube tip 48 and the conical surface 51. As a result of the air flow in this region, the static pressure component is reduced and the fuel pressure in the line 38 is able to overcome the surface tension at the tube tip 48 with the result that fuel is drawn from the capillary tube 47 and atomized. The resulting mixture of air and fuel travels adjacent the axis of the inlet passage 6 into the combustion chamber 8 with little risk of wetting the walls of the passage 8.

Towards the end of the induction stroke in the chamber 8, another chamber will be undergoing its induction stroke under higher speed flow conditions than the first combustion chambers. Accordingly, the nozzle associated with this second combustion chamber will take over and will atomize all the fuel flow available from the accumulator and distributor valve 30. As a result, the last part of the charge entering the first combustion chamber may consist essentially of air alone with the result that a stratified charge may be possible within the combustion chamber.

In order to supply enriched fuel for acceleration, a device 61 sensitive to rapid movement of the throttle linkage 28 in the opening direction may feed a signal to the electronic control unit 18 to cause the latter to operate the solenoid-operated valve 20 continuously for a short time so as to greatly increase, temporarily, the fuel supplied to the nozzle 39.

In the system shown in Figures 3 and 4, elements corresponding to the system shown in Figures 1 and 2 are indicated by the same reference numerials increased by 100. In this system, the variable constriction 116 is upstream, in the direction of fuel flow, of pulser valve 115. Fuel filters F are advantageously included in the fuel supply lines.

The nozzle construction shown in Figure 4 may also be used in the system of Figures 1 and 2. In the arrangements shown in Figure 4, the nozzle 139 is retained in position by a clamping plate 161 secured by a screw 162. An additional sealing O-ring 163 is located in a groove 164 in the non-screw threaded shank 165 of the nozzle.

The orifice member 149 has its frusto-conical surface 151 extending for substantially the whole length of the orifice member at a semi-vertical angle of 15°. If A is the diameter of the outlet orifice, B is the internal diameter of the portion of the orifice member surrounding the end of the capillary tube 147 and C is the spacing between the end of the capillary tube 147 and the end of the cylindrical portion of diameter B, the following tests results were obtained using a capillary tube of internal diameter 0.6 mm and external diameter 0.89 mm, the flow rates corresponding to continuous operation of the nozzle;

1. $A^{\emptyset}$ = 0.381 mm $\emptyset$ and $B^{\emptyset}$ = 1.2 mm C = 0.381 mm.

Very good atomisation at low flows, (30-80cc/min) but at flows over 80cc/min start to form a jet and at 100cc/min it becomes a pure jet.

2. $A^{\emptyset}$ = 0.381 mm $\emptyset$ and $B^{\emptyset}$ = 1.1 mm C = 0.381 mm.

Just as good atomisation as above but can flow up to 100cc/min before we can see the jet start, it becomes a pure jet at around 120/130cc/min.

3. $A^{\emptyset}$ = 0.381 mm $B^{\emptyset}$ = 1.2 and C = 2.54 mm.

A very narrow cone with good atomisation and shut-off point but starts to form a jet at around 100cc/min and forms a pure jet at 150 cc/min.

$A^{\emptyset}$ = 0.381 mm $B^{\emptyset}$ = 1.2 and C = 1.524 mm.

Not such a narrow cone as above and around the same shut-off-point as well as flows with produc s a jet.

4. $A^{\emptyset}$ = 0.381 mm $B^{\emptyset}$ = 1.3 and C. = 0.381 mm.

Good atomisation to around 200 cc/min then starts to become a jet. Shut-off-point is around (70/80 cc/min).

Further details of the fuel delivery system and its electronic control unit are disclosed in our parent application no. 82901977.7 - 0083348.

CLAIMS

1. Apparatus for delivering successive charges of fuel to a working chamber of an internal combustion engine from a liquid fuel supply line (38,138) the flow rate to which is controlled in accordance with operating conditions of the engine, comprising a nozzle (39,139) mounted in the side wall of an inlet duct (5, 105) leading to the working chamber (8), the nozzle comprising a small bore fuel delivery tube (47,147) connected to the supply line and mounted in an air passage (52,152) connected to received air from a supply (54,154) by passing the engine throttle, the air passage being convergent to an outlet (50, 150) for delivering fuel and air into the inlet duct (5, 105), characterised in that the delivery tube (47,147) is continuously connected to the supply line (38,138) and in that the pressure maintained in the supply line (38,138) in relation to the dimensions of the delivery tube is insufficient to discharge a charge of fuel from the delivery tube in the absence of air movement in the air passage so that a charge of fuel is delivered by the delivery tube only during induction of a charge of air into the combustion chamber.

2. Apparatus according to claim 1, characterised in that the air passage (52,152) is convergent around the end of the delivery tube (48,148).

3. Apparatus according to claim 1 or 2, characterised in that the inlet end of the small bore delivery tube (47) is oblique.

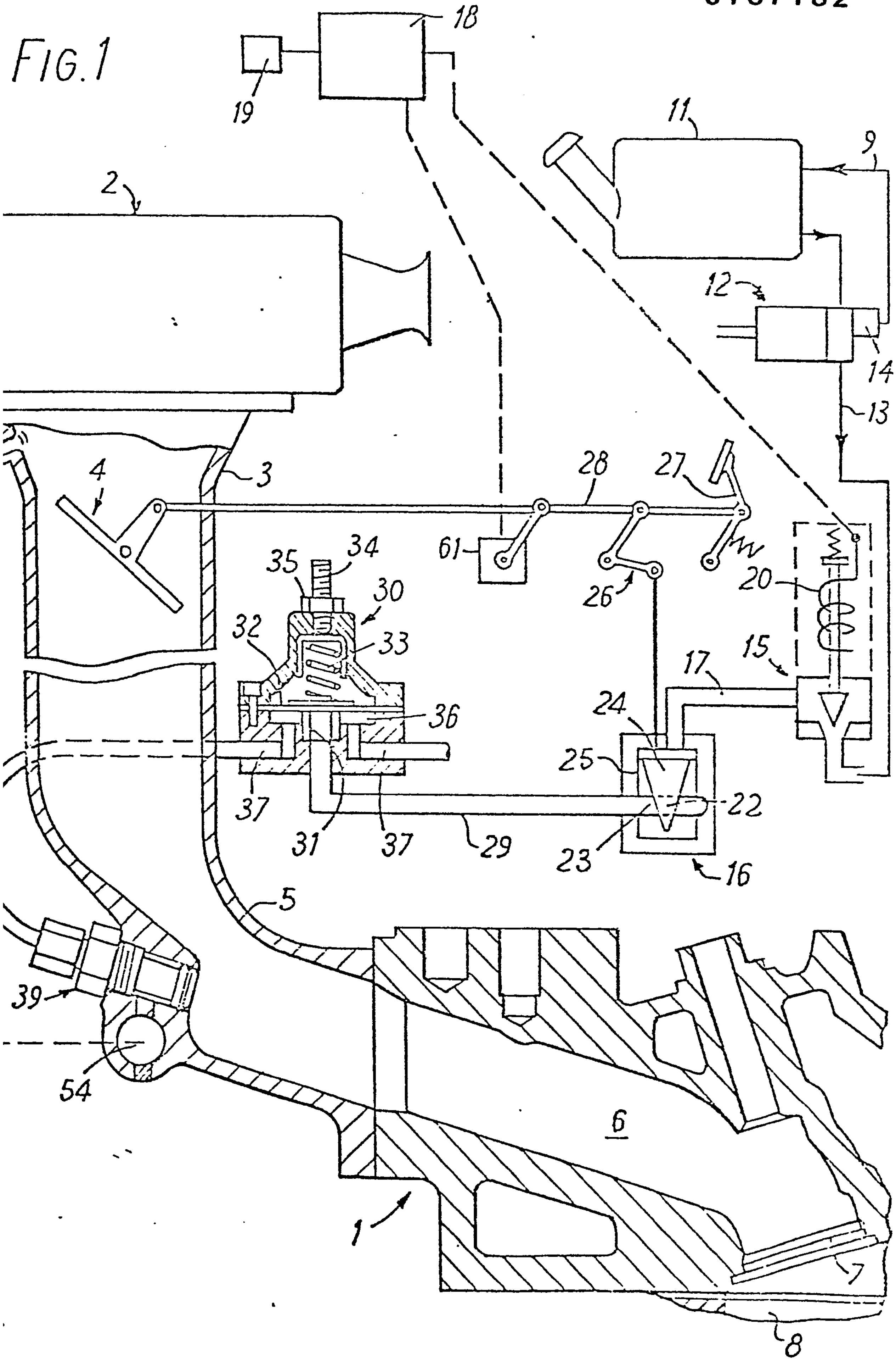
4. Apparatus according to claim 1 or 2, characterised in that the convergent portion (151) of the air passage is sufficiently gradually convergent over a sufficient length to ensure acceleration of the airflow therethrough during an induction stroke to a supersonic velocity.

5. Apparatus according to any of the preceding claims, characterised in that the air inlet duct (5) is formed with a venturi-like constriction (56, 156) adjacent the nozzle.

6. Apparatus according to claim 5, characterised in that the constriction (56,156) is insufficient to cause supersonic air velocities therein.

7. Apparatus according to any of the preceding claims for a multicylinder engine having an inlet manifold defining a plurality of inlet ducts and a said nozzle (39, 139) in each said duct characterised in that the supply lines (38,138) for all the nozzles are continously connected to the same said source (30,130) of fuel.

FIG.1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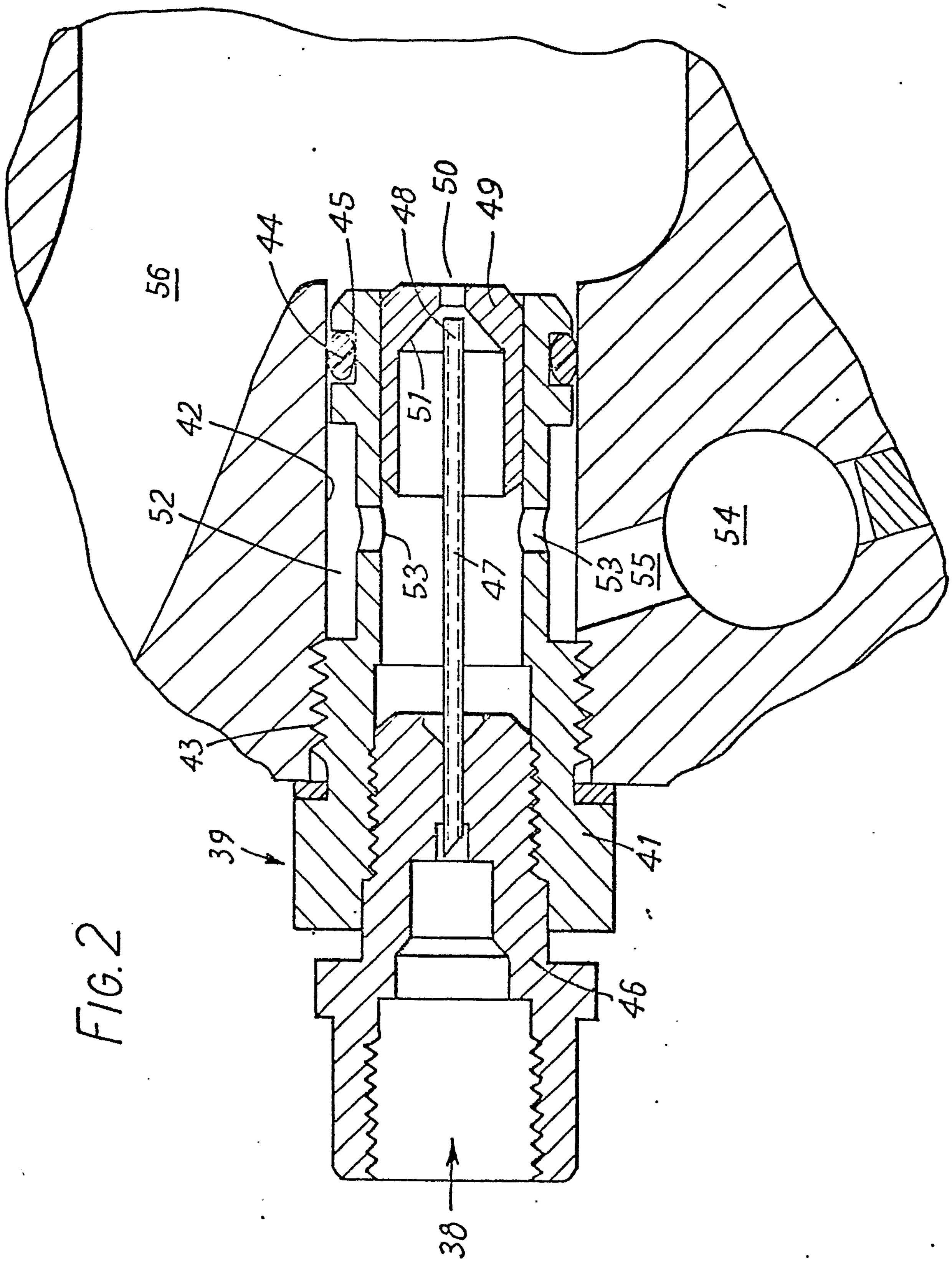

FIG. 2

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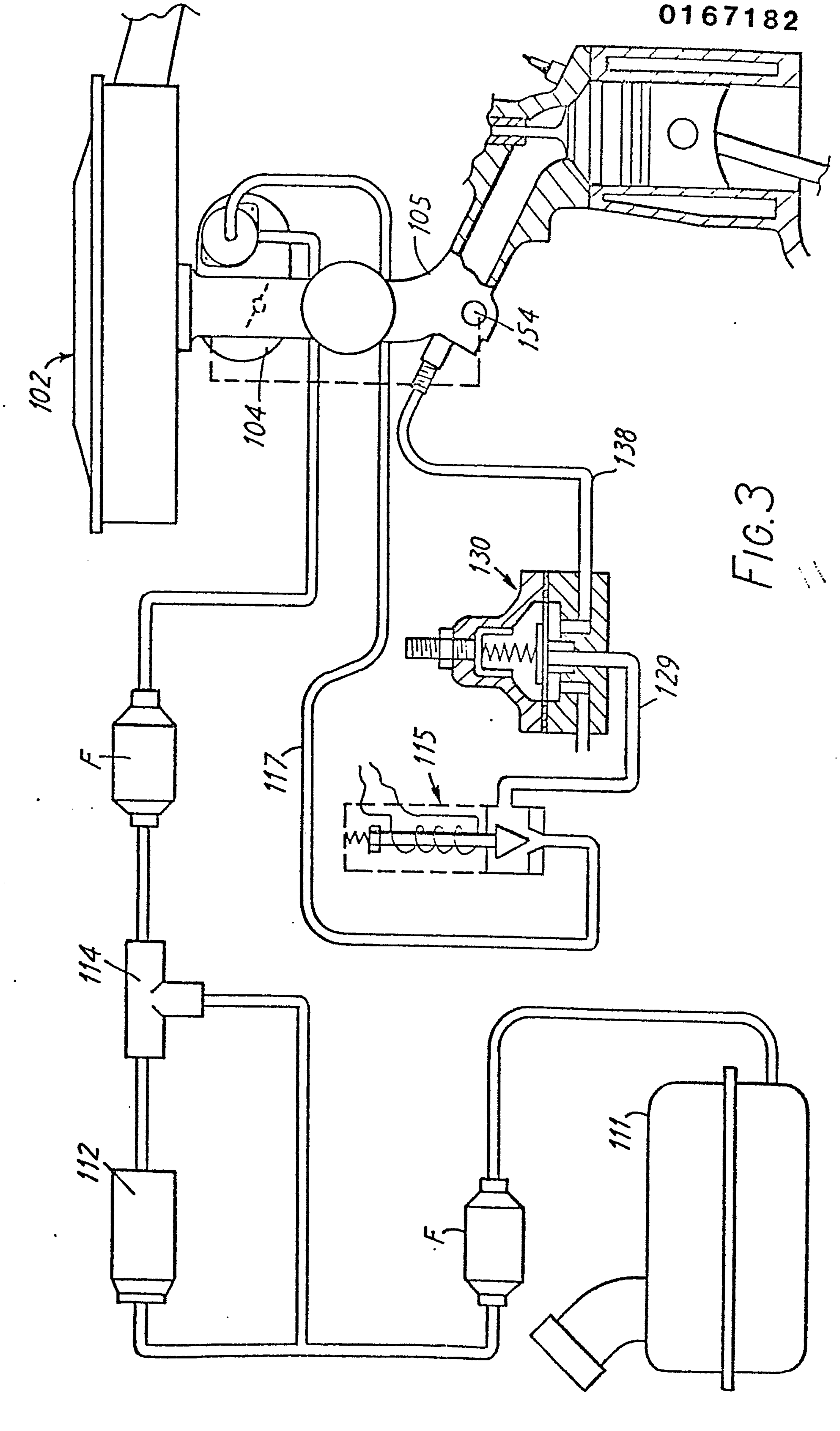

FIG.3

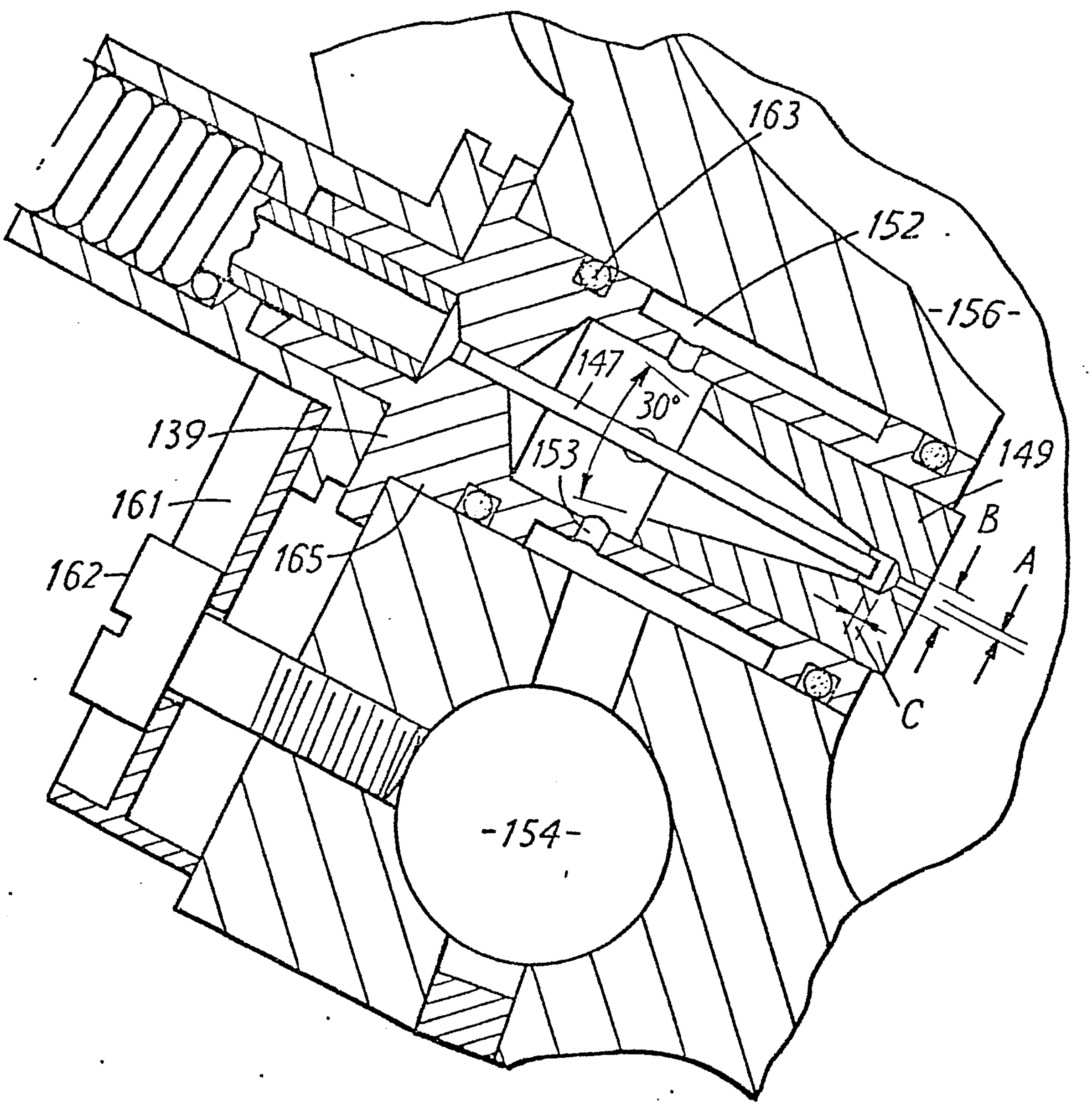

FIG.4