Sept. 6, 1960 R. G. ENGEL, JR 2,951,643

FUEL INJECTOR WITH PILOT INJECTION

Filed March 13, 1958 2 Sheets-Sheet 1

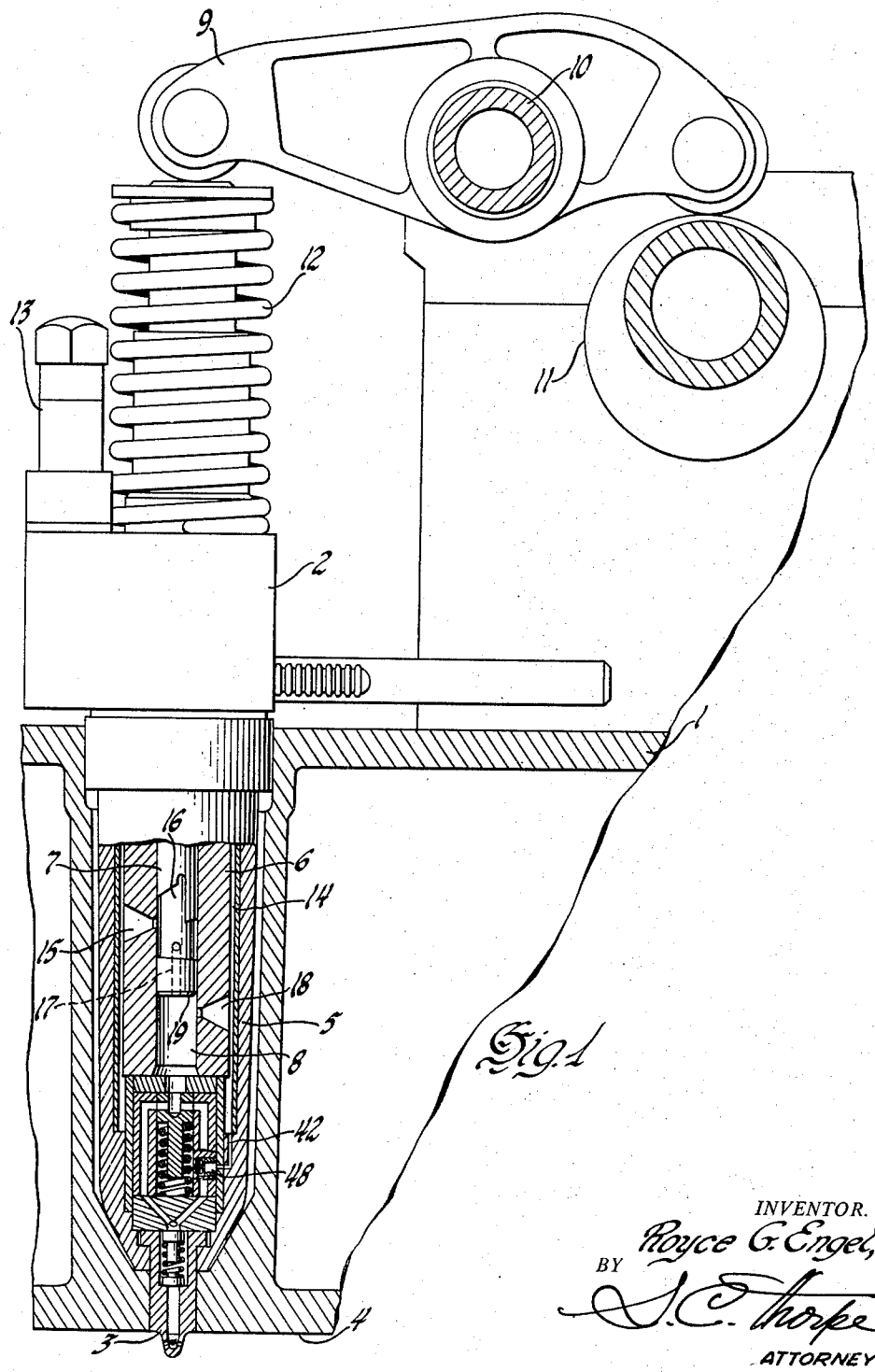


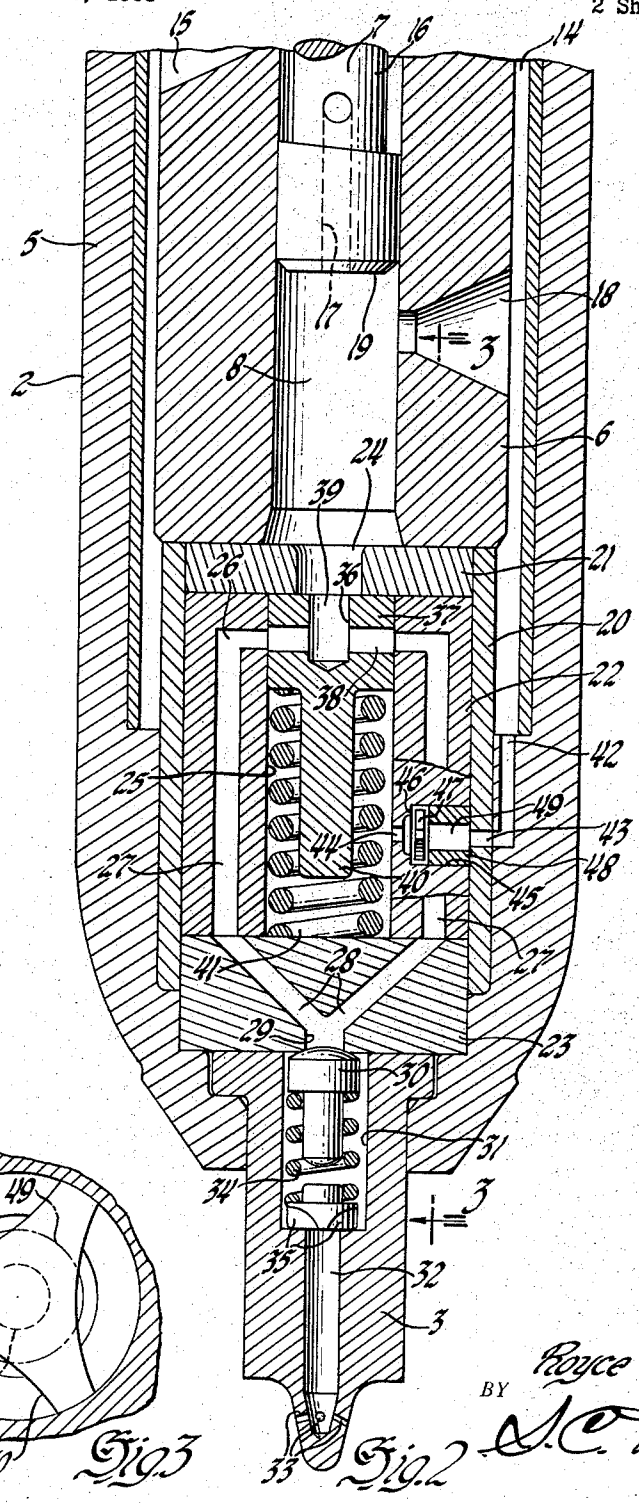
Fig. 1

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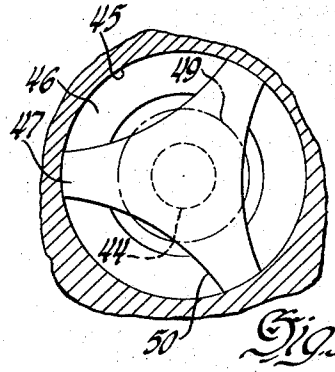


Fig. 3

Fig. 2

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FUEL INJECTOR WITH PILOT INJECTION

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1 Claim. (Cl. 239—90)

This invention relates to fuel injection devices such as are used for delivering metered amounts of fuel to internal combustion engines, and particularly to such devices wherein the injection is effected in two distinct phases, i.e., a "pilot" or primary injection and a "main" or secondary injection with a "gap" or time interval therebetween.

Injection of the fuel in this manner is advantageous, particularly with diesel engines, because the primary injection charge which can be made relatively small in quantity serves to initiate the combustion in the engine cylinder in advance of the main charge, thereby reducing the rate of pressure rise and the peak pressure developed in the combustion chamber, with consequent increased efficiency and lowering of the noise level of the combustion process. It has been found very important in this type of injection that both the primary and main charges be precisely timed, and to insure this it is a practical necessity that the charge forming pressure be maintained at or higher than the primary injection pressure during the gap between injections.

While it has heretofore been proven possible to accomplish this by mechanical means through the addition of an extra groove or control edge on the plunger and additional ports in the bushing of a conventional "jerk type" injector, I have found that at least equal timing precision and substantially less harshness and wear on the operating parts can be obtained with the use of a hydraulically controlled valve in the pump delivery line to the injection nozzle. This control valve, in accordance with my invention, operates in response to charge forming pressure developed by the pump and serves to time the ending of the primary injection and start of the main injection, while preventing any diminution of the pump delivery pressure, in an improved manner.

A better understanding of the nature and advantages of the invention will be apparent from the following description of one preferred embodiment thereof wherein:

Figure 1 is a longitudinal sectional view through a portion of an internal combustion engine, incorporating a unit fuel injector-pump constructed in accordance with the invention.

Figure 2 is an enlarged fragmentary sectional view, similar to that of Figure 1, showing the hydraulic control features of the injector-pump in greater detail.

Figure 3 is a further enlarged fragmentary view taken substantially on the line 3—3 of Figure 2.

Referring now in detail to the drawings, and first to Figure 1, an internal combustion engine cylinder head is indicated at 1, in which is mounted a unit fuel injector-pump 2. The lower end of this injector-pump terminates in a fuel nozzle spray tip 3 on the combustion chamber side 4 of the cylinder head. Within the stationary body 5 of the injector-pump is shown the usual fixed bushing 6 in which reciprocates a plunger element 7. The chamber 8 within the bushing below the plunger constitutes the charge forming or pumping chamber of the unit. The upper end of the plunger 7 is arranged for reciprocation by the usual rocker 9 journaled on a shaft 10 supported above the cylinder head and operated by an engine cam 11. A plunger return spring 12 cooperates with the rocker 9 in effecting plunger reciprocation. Inlet fuel supply and return fuel passages (not shown) in the body 5 connect respective external fittings (one of which is shown at 13) with a fuel receiving chamber 14 which extends annularly and axially about the bushing 6 within the body 5. This fuel receiving chamber 14 with its external supply and return connections thus constitutes a fuel supply source for the pumping chamber 8. Upper and lower radial ports 15 and 18 extend through the bushing 6 and cooperate with the external groove 16, internal passage 17 and lower end 19 of the plunger in a well known manner to form the fuel charge in the pump chamber 8 during each plunger operating cycle. That is to say, during each upward stroke of the plunger fuel is drawn in from the receiving chamber 14 through the upper and lower ports 15 and 18 to fill the pumping chamber 8, and then during the initial downstroke a portion of this fuel is bypassed back to the receiving chamber 14 via the lower port 18 and also via the plunger passage 17 and groove 16 and bushing upper port 15. With continued downward movement of the plunger, after the plunger lower end 19 closes lower port 18 and the upper end of the groove 16 closes the upper port 15 fuel pressure is built up in the chamber 8, and this continues until the lower end of the plunger groove 16 uncovers the lower port 18 whereupon the pumping chamber is relieved via the plunger passage 17 and groove 16 to the receiving chamber via this lower bushing port 18.

As best seen in Figure 2, between the nozzle spray tip 3 and the lower end of the pump bushing 6 is a valve assembly which provides means defining a delivery passageway for the injection fluid. Included in this assembly is a spacer sleeve 20 enclosing an upper plate 21, a valve body 22 and a transfer block 23 in stacked, end-to-end relation. The plate 21 abuts the lower end face of the bushing 6 and is provided with a central aperture 24 which serves as an inlet to the valve body having open communication with the pumping chamber 8. The valve body has a central bore 25 extending therethrough to provide a valve chamber which is open at its upper end to the pumping chamber 8 through the plate aperture 24, and closed at its lower end by the upper face of the transfer block 23. Adjacent, but below its upper end, this bore 25 is provided with an annular internal groove 26 which serves as a valve chamber outlet communicating with one or more longitudinally drilled passages 27 extending upward thereto through the valve body walls from the lower end of the valve body. These passages 27, in turn, connect with respective branch passages 28 in the transfer block 3. The latter passages 28 intersect at their lower ends with a common outlet port 29 which is normally maintained closed by a spring biased injection valve 30. This valve 30 operates in a recess 31 formed in the upper end of the spray tip 3, and the lower end of this recess is connected by a longitudinal passage 32 with the usual spray orifices 33 by which the fuel is discharged into the engine combustion chamber. Between the biasing spring 34 for the injection valve 30 and the bottom of the recess is a combined valve stop and spring seat which is notched at 35 about its periphery to allow fuel to ener the passage 32 from the recess.

Slidably fitting the bore 25 of the valve chamber 22 is a piston or plunger type hydraulic control valve 36. The annular upper end portion 37 thereof defines land means which is normally positioned as shown between the open end of the bore and the outlet groove 26. Below this land portion 37 is a cross passage 38 which is intersected at its center by a longitudinal passage 39, and

these two passages serve in the position of the control valve as shown to interconnect the pumping chamber with the outlet groove **26** and passages **27**, **28**, **29**, recess **31**, passage **32** and spray orifices **33** when sufficient fuel pressure exists in the pumping chamber **8** to unseat the injection valve **30**. The lower end of the hydraulic control valve **36** is in the form of a depending stem **40** to limit its downward opening movement by abutment with the transfer block **23**. A coil compression spring **41** surrounds this stem **40** and serves to bias the hydraulic control valve upwardly against the plate **21**. The annular land portion **37** of the control valve is of sufficient width axially of the valve to operably block the outlet groove **26** during downward movement of the control valve for a time period sufficient to obtain the desired "gap" of no injection between the primary and main injection charges. Sufficient clearance exists between the lower end of the control valve stem **40** and the transfer block to accommodate travel of the control valve to a position in which the upper edge of the land portion **37** clears the lower side of the outlet groove **26**, thus enabling full flow of injection fluid directly through the valve body chamber from the pumping chamber **8** to the outlet groove **26** during the "main" injection.

A flow connection is provided to vent the valve body bore **25**, below the control valve **36**, to the fuel receiving chamber **14**. This connection is illustrated by the passages **42** and **43** in the injector-pump body **5** and spacer sleeve **20** and a radial port **44** and counterbore **45** in the valve chamber **22**. A shoulder **46** at the bottom end of this counterbore forms a valve seat for a variable restriction wafer type valve **47** (best seen in Figure 3). A bushing **48** having a bore **49** is fitted in this counterbore and forms an opposite seat of increased cross-sectional area for the wafer valve **47**. This wafer valve is cut away in one or more places on its periphery to provide openings as indicated at **50** (Figure 3) whereby fuel may pass through the valve in its passage through the flow connection formed by the passages **42**, **43**, **44** and bushing **48**. The larger area of the seat formed by the bushing **48**, relative to the area of the seat **45** formed by the counterbore, serves to restrict the fuel flow past the valve via its cutout portions **50** in the direction outwardly of the valve chamber in comparison with such flow in the reverse direction.

It will accordingly be appreciated that during each downward or charge forming stroke of the pump plunger **7** fuel pressure will initially build up in the pumping chamber **8** and the passageways **38**, **39**, **26**, **27**, **28**, **29** until the injection valve **30** opens to permit the primary injection charge to be delivered through the spray orifices **33**. Such fuel pressure buildup in the pumping chamber also causes the hydraulic control valve **36** to move downwardly against the force of its biasing spring **41** and the pressure of fuel below the control valve. This latter fuel pressure is initially equal to that of the pump supply pressure in the fuel receiving chamber **14**, however, outward flow of fuel from the valve chamber bore through the passage **44** moves the wafer valve **47** against the bushing **48**, resulting in some pressure buildup below the control valve **36**. This retards downward movement of the control valve, but does not fully restrain it because of the higher fuel pressure acting on it from above. When the control valve **36** has traveled downwardly a sufficient distance that the land portion **37** closes off the outlet groove **26** further pilot injection

ceases and remains stopped pending further downward movement of the control valve sufficient to again uncover the outlet groove **26**. When the latter event occurs, main injection begins by fuel flowing over the upper end of the control valve and thence via the outlet groove **26**, passage **27**, etc., to again force open the injection delivery valve **30**. On the return stroke of the plunger the control valve rises rapidly to its initial position shown under the force of its biasing spring **41**, the reduced seating area of the wafer valve seat **46** enabling the wafer valve to pass fuel back into the valve body bore **25** from the fuel receiving chamber **14** at a sufficient rate to avoid retarding the control valve return movement.

While only a single preferred embodiment of the invention has been disclosed, it is appreciated that numerous minor changes in the construction and arrangement of the parts may be made without departing from the spirit and scope of the invention as defined in the following claim.

I claim:

In a fuel injector providing for pilot injection in advance of a main injection delivery, a fuel pumping chamber having an element movable therein to create an increasing fuel supply pressure, an injection nozzle, and means for conducting injection fuel from the pumping chamber to the nozzle including a valve chamber open at one end to receive fuel from the pumping chamber and closed at its opposite end, said chamber having a side port connected to the nozzle, said port being spaced from said open end of the chamber, a slide valve in the chamber movably responsive to pumping chamber pressure including a portion operable to block the side port, said portion being normally disposed between the side port and said chamber open end but movable to the opposite side of said port from said chamber open end to connect the port to the pumping chamber, and means biasing the valve toward said chamber open end, said valve having a passage by-passing said portion for fuel flow from said pumping chamber to the side port in advance of said portion moving into blocking relation with the side port in response to increasing pumping chamber pressure, a fuel supply source for said pumping chamber, a flow connection between said closed end of the chamber and said source, and means restricting said flow through said connection from the valve chamber while accommodating relatively unrestricted flow therethrough from said source, said means comprising a valve element movable in response to direction of flow through said connection, said valve element having an opening therethrough, valve seats on opposite sides of said valve element, said valve seat on the side nearest said source being engageable with the valve element over an area overlapping a relatively large portion of said opening, and said valve seat on the side nearest said valve chamber being engageable with the valve element over an area overlapping a relatively small portion of said opening.

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