Sept. 10, 1946. G. S. KAMMER 2,407,610

FUEL INJECTION IN INTERNAL-COMBUSTION ENGINE

Filed Aug. 9, 1943

Fig. 1.

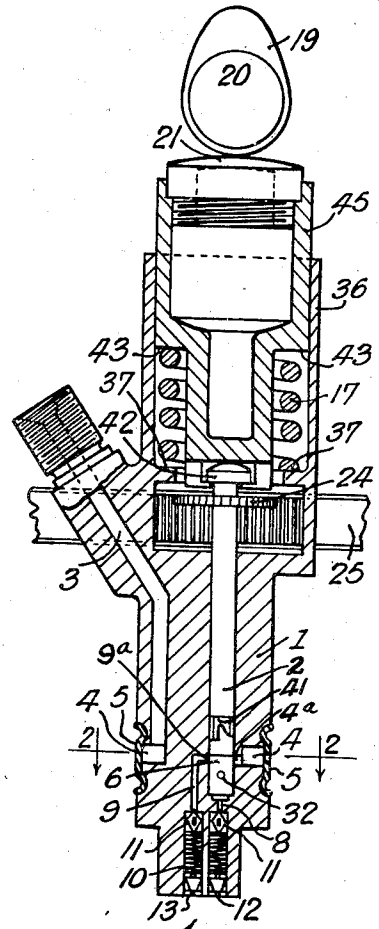


Fig. 2.

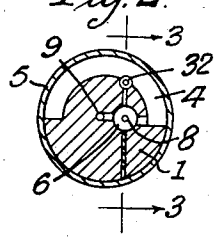
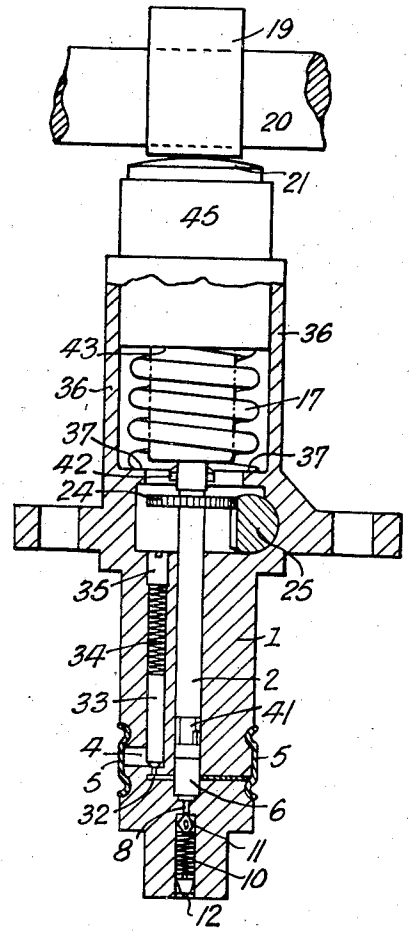


Fig. 3.



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FUEL INJECTION IN INTERNAL-COMBUSTION ENGINES

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4 Claims. (Cl. 103—41)

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This invention relates to fuel injection in internal combustion engines of the kind in which the fuel to be consumed in each cycle of each cylinder is injected into the compressed air charge in two portions at substantially different rates. It represents a further development of the invention described and claimed in my co-pending patent application No. 403,722, filed July 23, 1941.

In the patent application mentioned reference was made to the use of a rather large volume or capacity between the pumping space and the injector needle valve leading to the jets for the primary or pilot rate of injection, and it was proposed to make use of the compressibility of the fuel for limiting the maximum pressure due to the restricted discharge area in connection with a single or steady cam lift for the pump plunger.

That method is quite satisfactory in cases where (*a*) the pump plunger is not called upon to perform more than about 1000 injections per minute, and (*b*) where the pump unit is located rather far away from the nozzles and the capacity can be so formed that it acts as a trap, so to speak, for the ram effect induced in the pipes during operation, but it is difficult to provide for in other cases.

It is an object of the invention to provide a fuel pump for high speed operation in which the maximum pressure is so limited.

A further object of the invention is to provide a fuel pump combined with the injection nozzles in which the maximum pressure is so limited.

Another object is to provide means by which the crank angle during which pilot injection is to take place may be predetermined more or less independently of the amount to be injected during this crank angle.

Yet a further object of the invention is to provide limited leakage of the fuel into the pump suction space during pilot injection to restrict the quantity and pressure of the fuel.

Other objects will appear from the following description of a pump and nozzle combination shown in the accompanying drawing, in which

Figure 1 is a central longitudinal section through the combination,

Figure 2 is a transverse section taken on the line II—II of Figure 1, and

Figure 3 is a central longitudinal section on the line III—III of Figure 2, that is at right angles to the section of Figure 1.

Referring to the drawing, a pump cylinder 1 contains a pump plunger 2, in which a groove 41 is shaped to vary the timing of port opening as

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disclosed in my co-pending patent application No. 403,722, filed July 23, 1941. Fuel is supplied through a duct 3 to an inlet trunk 4 formed as a portion of an annulus on the outer surface of the pump cylinder 1, which may be sealed by a sleeve 5. The pressure space 6 of the pump is in direct communication with the trunk 4 through a port 4a when the plunger 2 is in the uppermost position as shown, but this communication is interrupted when the plunger has moved a short distance downwards.

Two outlet leads 8 and 9 are connected to the pressure space 6, of which 8 is always open and provides the pilot fuel, while 9 is controlled as to opening and closing by movement of the plunger 2 over an outlet port 9a, and provides the main charge of fuel. These outlet leads 8 and 9 convey the fuel to the pilot fuel jet 12 and the main fuel jet 13 respectively through check valves 11 loaded by springs 10.

The plunger 2 has a head 42, which is embraced by the lower end of a tappet 45, so that the plunger positively follows the movements of the tappet. The upper end of the tappet 45 slides in an upward extension 36 of the pump cylinder 1 and is urged upwards by a plunger return spring 17, which bears on a shoulder 43 of the tappet 45 and an inward flange 37 of the extension 36. An actuating cam 19 on the camshaft 20 bears on a mushroom 21 forming a part of the tappet 45.

For rotating the plunger 2 to bring different parts of the helical edge of the groove 41 into operation and so to vary the quantity of fuel injected, there is provided a gear wheel 24 which may be integral with the plunger 2 and is located to engage a rack 25. The rack teeth are wide enough to retain engagement with the gear wheel 24 at all positions of the plunger 2 in its working stroke. The rack bar 25 is of round section at the part away from the teeth and is adapted to slide in a suitably machined recess in the pump body 1 to adjust the quantity of fuel delivered at each pump stroke.

A small port 32, which I propose to call a control orifice, is located in the pumping space 6 to be covered by the pump plunger and so closed at a certain point in the stroke. There may also be a check valve 33 loaded by a spring 34 and located in a bore sealed by a plug 35. This valve in its closed position closes the passage leading from the control orifice 32 to the inlet trunk 4. The check valve 33 has axial grooves (not shown) to permit fuel from the trunk 4 to pass to the space occupied by the spring 34 and vice versa,

The plunger 2 when moving downwards first closes the outlet port 9a, then the inlet port 4a, thus sealing the space 6 from the trunk 4 except for the control orifice 32. As the pressure rises, discharge takes place through the lead 8, check valve 11 and jet 12 into the engine combustion space, and a rather larger amount of fuel is, at the same time discharged through the control orifice 32 into the inlet trunk 4 either directly or, if the optional check valve 33 is provided, by lifting the same from its seating.

The orifice 32 is so located that the inward edge of the plunger 2 passes over it just as the helical edge of the plunger uncovers the port 9a. Hereafter discharge can only take place through the jets 12 and 13, that is both the pilot and the main jets. Thus a quantity of fuel exactly corresponding to the displacement of the pump plunger 2, according to cam lift, is, in its entirety, discharged into the engine combustion space.

Obviously, by varying the size and shape of the control orifice 32, various amounts of pilot fuel can be arranged to be discharged into the engine combustion space. Also it is clear that more fuel is injected through the combined discharge of jets 12 and 13 than by jet or jets 12 alone, whilst some of the fuel displaced by the plunger 2 is being discharged into trunk 4.

12 may for example be one jet of .010" diameter for the pilot fuel and 13 may be four jets of similar size for the bulk or main fuel. Then the control orifice 32 should be so dimensioned that it discharges an amount of fuel substantially similar to that discharged by the four jets for main injection. This does not necessarily mean a similar total cross-sectional area, for the friction of the fuel, the capillarity of the orifices and the pressure difference between the trunk 4 and the engine combustion space must be taken into account.

If it is desired to inject the pilot fuel at higher pressure than the main fuel, the discharge characteristics of the control orifice 32 must be modified accordingly.

In such arrangements the pilot injection and the main injection vary in different ways with speed owing to several factors. Some of the factors are the rise of injection pressure and the rise of compression pressure in the engine cylinder with rising speed, the constancy of fuel admission pressure and the variation of the volumetric efficiency of the pump. The check valve 33 can be arranged to alter the discharge characteristics in the desired manner.

It is also possible to arrange, within the cylinder or body 1 a controllable check valve, which is in continuous communication with the space 2. This check valve could be coupled with the plunger 2 in such way that the rotation of the plunger 6 would also rotate the check valve, preferably a needle-valve having a thread, and thus vary the area through which continuous discharge would take place from the space 6 during injection. At low speeds the area would be considerably restricted, at high speeds increased.

It is in most cases desirable during starting that no pilot fuel should reach the engine cylinder, as such fuel cannot be burnt within the necessary short time owing to lower compression of the air charge in a cold engine. With a pump of the kind now described the "start" position of the pump plunger is one which will give injection during a considerably larger proportion of the pump stroke than at full load and is not utilised during normal operation of the engine.

It is thus possible to cut away the top edge of the pump plunger 2 for a portion of the circumference corresponding to the "start" position only. While in normal running injection commences well before the inner dead centre, this arrangement will confine injection during starting to the main fuel and shift the commencement of injection to a piston position near the inner dead centre, because the cut-away portion ensures that the pumping space is not closed until the orifice for the main injection is uncovered by the plunger. Such provision will greatly assist in starting.

What I claim is:

1. A fuel injector for an internal combustion engine of the kind in which fuel to be consumed in each working cycle is injected uninterruptedly into a compressed air charge in two portions, namely a pilot fuel portion and an immediately following main fuel portion, the two portions being injected at substantially different rates, comprising a jerk type pump having a cylinder formed with a compression space, a plunger operable in said compression space, a fuel inlet passage terminating in an inlet port in the wall of the compression space at a part traversed by said plunger, a first outlet from the compression space out of reach of the plunger for the pilot fuel, a second outlet from the compression space separate from said first outlet and having an outlet port opening into the compression space wall at a part thereof traversed by the plunger for discharging the main fuel portion, a groove in the plunger located to uncover said outlet port and said inlet port in succession during the working stroke of said plunger, and a control orifice in the wall of said compression space separate from said outlet and being located to be covered by said plunger during the latter part of said working stroke and being adapted to discharge fuel from said compression space.

2. A fuel injector for an internal combustion engine of the kind in which fuel to be consumed in each working cycle is injected uninterruptedly into a compressed air charge in two portions, namely a pilot fuel portion and an immediately following main fuel portion, the two portions being injected at substantially different rates, comprising a jerk type pump having a cylinder formed with a compression space, a plunger operable in said compression space, a fuel inlet passage terminating in an inlet port in the wall of the compression space at a part traversed by said plunger, a first outlet from the compression space out of reach of the plunger for the pilot fuel, a second outlet from the compression space separate from said first outlet and having an outlet port opening into the compression space wall at a part thereof traversed by the plunger for discharging the main fuel portion, a circumferential groove in the plunger located to uncover said outlet port and said inlet port in succession during the working stroke of said plunger, and a control orifice in the wall of said compression space separate from said outlet and being located to be covered by said plunger during the latter part of said working stroke and communicating with said inlet passage.

3. A fuel injector for an internal combustion engine of the kind in which fuel to be consumed in each working cycle is injected uninterruptedly into a compressed air charge in two portions, namely a pilot fuel portion and an immediately following main fuel portion, the two portions being injected at substantially different rates,

comprising a jerk type pump having a cylinder formed with a compression space, a plunger operable in said compression space, a fuel inlet passage terminating in an inlet port in the wall of the compression space at a part traversed by said plunger, a first outlet from the compression space out of reach of the plunger for the pilot fuel, a second outlet from the compression space separate from said first outlet and having an outlet port opening into the compression space wall at a part thereof traversed by the plunger for discharging the main fuel portion, a circumferential groove in the plunger located to uncover said outlet port and said inlet port in succession during the working stroke of said plunger, and a control orifice in the wall of said compression

space separate from said outlet and being located between said ports and said first outlet so as to remain uncovered by said plunger during the first part of the plunger working stroke and to then be covered by said plunger during the latter part of the plunger working stroke when said outlet port is uncovered by said circumferential groove, said control orfice communicating with said intake passage.

4. A fuel injector as set forth in claim 2 including a check valve interposed between said control orifice and said inlet passage and being arranged to open towards said inlet passage in response to pressure in said control orifice.

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