

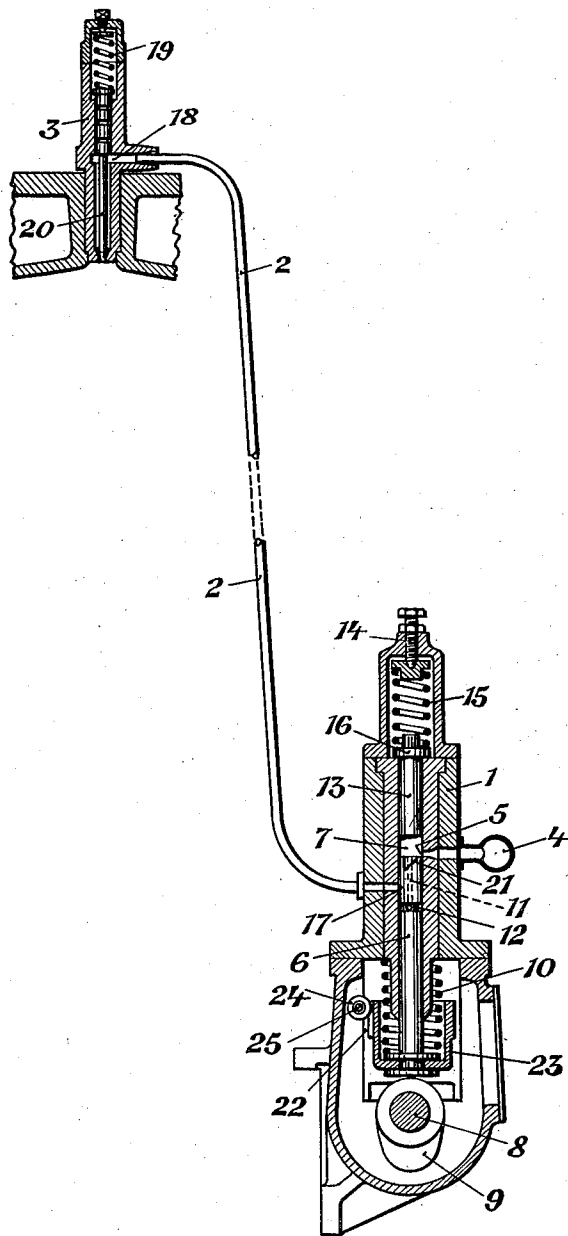
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FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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This invention relates to fuel injection apparatus for internal combustion engines operating with airless or solid injection of fuel.

When, as in some known forms of injection apparatus, the injection period is terminated by releasing the pressure within the fuel supply pipe, separate means have to be provided for effecting such release and in addition there is a tendency at low loads or low speeds of the engine for injection to be interrupted or rendered intermittent due to the pressure of the fuel being insufficient to open the fuel injection valve. With a view to providing a fuel pressure sufficient to open the injection valve, proposals have been made to furnish the injection valve with an accumulator piston whereby the minimum quantity of fuel which can move the accumulator piston is injected at a sufficient pressure when the fuel valve is opened. Since such arrangements however necessitate supplying the fuel to the injection valve at a high pressure even for the minimum charge, the pressure for large charges, that is to say at heavier loads, is excessive with the result that the injection apparatus is bulky and expensive to construct whilst the power necessary for supplying the fuel is increased. Furthermore, such arrangements incorporate valves in the fuel delivery pipe, which valves tend to have undesirable effects on the flow of the fuel to the injection valve.

Fuel injection apparatus according to the present invention comprises a fuel pump from which the fuel charge is delivered by the joint action of two pressure members one of which is operated in accordance with the speed of the engine whilst the other is independent of such speed, and a fuel delivery pipe through which the fuel charge passes from the pump to a fuel injection valve which cuts off communication between the delivery pipe and the working chamber of the engine to determine the end of the injection period, the commencement of the injection period being determined by a piston or like slide valve controlling communication between the working chamber of the pump and the delivery pipe.

Thus, the tendency for injection to be interrupted due to the fuel pressure being insufficient at low loads or low speeds of the engine to open the injection valve, is overcome.

One construction of fuel injection apparatus according to the invention is illustrated somewhat diagrammatically and by way of example in the accompanying drawing. In the construction illustrated fuel is delivered by a fuel pump 1 through

a delivery pipe 2 to a fuel injection valve 3 whereby the fuel is injected into the working chamber of the engine (not shown). Fuel is drawn by the pump 1 from a supply pipe 4 and enters the pump through an inlet port 5 when this is uncovered by the pump plunger 6, whereby a fuel charge flows into the working chamber 7 of the pump. Reciprocation of the plunger 6 is effected by means comprising a shaft 8 carrying a cam 9, and a spring 10 which maintains the plunger 6 in engagement with the cam 9. Thus, the plunger 6 is moved on its compression stroke by the cam 9 and is moved on its return or suction stroke by the spring 10.

The plunger 6 has an axial bore 11 which communicates between the working chamber 7 and an annular recess 12 in the plunger 6. The pump plunger 6 cooperates with an accumulator piston 13 the loading of which can be adjusted by means of a stud 14 bearing on a loading spring 20, the piston 13 having an annular flange 16 whereby inward movement of the piston towards the pump plunger 6 is limited.

Assuming that the fuel charge has been drawn into the working chamber 7 of the pump and the 25 plunger is moving on its compression stroke, the charge in the working chamber 7 is subjected to pressure between the plunger 6 and accumulator piston 13, the pump plunger, accumulator piston and fuel charge moving together against the 30 action of the spring 15 which is thus compressed. Shortly before the plunger 6 has reached the outer dead centre position, that is to say just before the plunger reaches the end of its compression stroke, the annular recess 12 registers 35 with an outlet port 17 through which the delivery pipe 2 communicates with the cylinder of the fuel pump 1. The pump plunger 6 and accumulator piston 13 thereupon move towards each other so as to deliver the fuel charge to the 40 delivery pipe 2 as hereinafter described.

Prior to the delivery of fuel to the pipe 2 from the pump 1 the pressure in the pipe 2 is substantially equal to that pressure in the chamber 18 of the injection valve 3 which will permit the 45 loading spring 19 to close the needle valve 20. The pressure necessary within the chamber 18 in order to raise the needle valve 20 is, however, greater than that required to return the valve to its seat since as soon as the needle valve is 50 raised the area thereof upon which the fuel pressure can act exceeds the area available for this purpose when the needle valve is in its closed position.

When the outlet port 17 registers with the annu- 55

lar recess 12 in the plunger 6 the fuel charge is delivered to the outlet port 17 partly under the pressure applied by the plunger 6 whose movement is in accordance with the speed of the engine, and partly under the pressure applied by the accumulator piston 13 which moves independently of such speed. The fuel charge is delivered to the outlet port 17 in a pressure impulse or "wave", this wave being transmitted substantially at the speed of sound through the delivery pipe 2 to the chamber 18 of the fuel injection valve 3. When, however, the pressure wave reaches the chamber 18 it is suddenly reversed since the needle valve 20 is not yet raised from its seat, so that the pressure where reversal occurs, i. e. within the chamber 18, will be substantially double that in the delivery pipe 2. In order therefore to raise the needle valve the pressure to which the fuel within the working chamber 7 of the pump is subjected need not exceed a value which lies between the pressure necessary for closing the needle valve 20 and that necessary to raise this valve from its seat. Thus, assuming, for example, that the closing pressure of the needle valve is 300 atmospheres and, for the purpose of avoiding premature opening of the valve, the spring 19 and needle valve 20 are constructed so that the opening pressure of the needle valve is 400 atmospheres, a static pressure in the pump chamber 7 of approximately 50 atmospheres above the closing pressure will be sufficient for the pressure wave to raise the needle valve 20.

As soon as the valve is raised from its seat the area of the needle upon which the fuel can act is increased and the needle valve will be returned to its seat when injection is complete and the pressure in the chamber 18 has fallen to a value which will permit the spring 19 to close the valve, the needle valve thus determining the end of the injection period. During the return or suction stroke of the plunger 6 this closes the outlet port 17 and the accumulator piston 13 returns to its seat, that is to say to its innermost position limited by the flange 16. Continued movement of the plunger 6 on its suction stroke produces a reduction of pressure in the working chamber 7, thereby drawing in a new charge of fuel, and the cycle is repeated.

For the purpose of regulating the quantity of fuel delivered the plunger 6 is provided with an oblique control edge 21 and a toothed rim 22 formed on an end cap 23, the teeth on the rim 22 being engaged by a worm 24 carried on a spindle 25. Thus, rotation of the spindle 25 by hand or by a governor on the engine will cause rotation of the plunger 6 so as to vary the angular position of the control edge 21 and thus the quantity of fuel delivered at each delivery stroke of the pump. It will however be understood that the quantity of fuel delivered may be controlled in any other suitable manner.

It will be seen that in fuel injection apparatus according to the invention the pressure at which fuel is delivered to the injection valve can be reduced to a pressure approximately half way between the closing pressure and the opening pressure of the fuel injection valve so that the delivery pressure can be maintained within moderate limits even when the opening pressure of the injection valve has to be high, without the risk of injection being interrupted at low loads or low engine speeds. Further, the use of a member in the form of a piston valve for controlling the point at which fuel delivery commences obviates the necessity for reductions or

increases in the dimensions of the delivery pipe. The pressure impulse or wave is thus transmitted through the outlet port and throughout the length of the delivery pipe without partial reversals or weakening of the impulse which would be liable to result if the commencement of fuel delivery were controlled, for example, by a poppet or like valve. The static pressure of the wave, that is to say the fuel pressure within the pump when delivery commences, need be only slightly greater than the mean value of the two pressures, namely the fuel pressure obtaining in the fuel injection valve prior to injection and the pressure necessary to open the injection valve.

The pressure members, that is to say the members under the joint action of which the fuel delivery to the delivery pipe takes place, may be constituted by opposed pistons either of which may serve as a slide valve to control the commencement of fuel delivery so that the provision of means external to the pump for controlling the commencement of fuel delivery is rendered unnecessary.

Since the pressure of the impulse or wave is not affected either by friction or by variations in the dimensions of the passages through which the fuel flows from the pump to the injection valve the pressure wave will ensure opening of the fuel injection valve even at small loads or when a small quantity of fuel is to be injected at each injection. The closing pressure of the needle valve is considerably lower than the opening pressure so that premature closing of the injection valve is prevented. Further, when the needle valve closes at the end of injection, opening of the valve before the next injection with consequent leakage of fuel into the combustion chamber of the engine is obviated without providing for release of the fuel pressure within the delivery pipe which release would necessitate refilling of the delivery pipe prior to each injection.

If desired, the mean delivery pressure may be higher for low loads than for high loads and the point at which fuel delivery commences may be adjusted and the delivery pressure regulated by separate regulating devices. Again, the fuel delivery may be controlled by a separate slide valve or piston valve arranged in the fuel delivery pipe, instead of by the pump plunger itself. In the case of multicylinder engines, a separate fuel pump may be provided for supplying fuel to each working chamber, the several pumps being, if desired, combined as a single unit with a common drive and common regulating means. Alternatively, a single fuel pump may supply fuel to several injection points through a distributor. At high loads, or when a large quantity of fuel is to be injected at each injection, means, such for example as throttling or by-pass devices may be brought into operation to damp the pressure wave in the delivery pipe as desired. Similarly the pressure wave may be rendered ineffective at high loads by bringing into communication with the delivery pipe or with the injection valve one or more pipes having closed ends so as to damp the wave. When damping means such, for example, as throttling or by-pass devices or closed-ended pipes are provided these may be brought into communication with the delivery pipe or injection valve automatically in accordance with the load on the engine. The injection valve may be so constructed and loaded that its natural period of vibration will exceed that of the pressure wave transmitted through the delivery pipe.

I claim:

1. In a liquid fuel injection apparatus for internal combustion engines, the combination of a fuel pump having a plunger driven by the engine and also provided with an accumulator piston, an injection valve for delivering the fuel to the working chamber of the engine adapted to be opened by the fuel pressure but incapable of being opened by the static pressure produced by said pump when the pump is delivering relatively small charges of fuel, a fuel conduit between the chamber of said pump and said injection valve adapted to facilitate the transmission of longitudinal vibrations in the fuel therein to said valve, and a timing valve on said pump plunger opening a direct passage from said pump chamber into said fuel conduit whereby longitudinal vibration of the fuel in said conduit is set up by the opening of the timing valve which causes a compressural wave in said liquid of sufficient magnitude to open the injection valve.
2. In a liquid fuel injection apparatus for internal combustion engines, a combination of a fuel pump having a plunger driven by the engine and also provided with an accumulator piston, an injection valve for delivering the fuel to the working chamber of the engine adapted to be opened by the fuel pressure but incapable of being opened by the static pressure produced by said pump when the pump is delivering relatively small charges of fuel, a fuel conduit between the chamber of said pump and said injection valve adapted to facilitate the transmission of longitudinal vibrations in the fuel therein to said valve, and a timing valve on said pump plunger opening a direct passage from the pump chamber into said fuel conduit whereby longitudinal vibration of the fuel in said conduit is set up by the opening of the timing valve which causes a compressural wave in said liquid of sufficient magnitude to open the injection valve.

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