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VALVE-ACTUATED FUEL INJECTION APPARATUS

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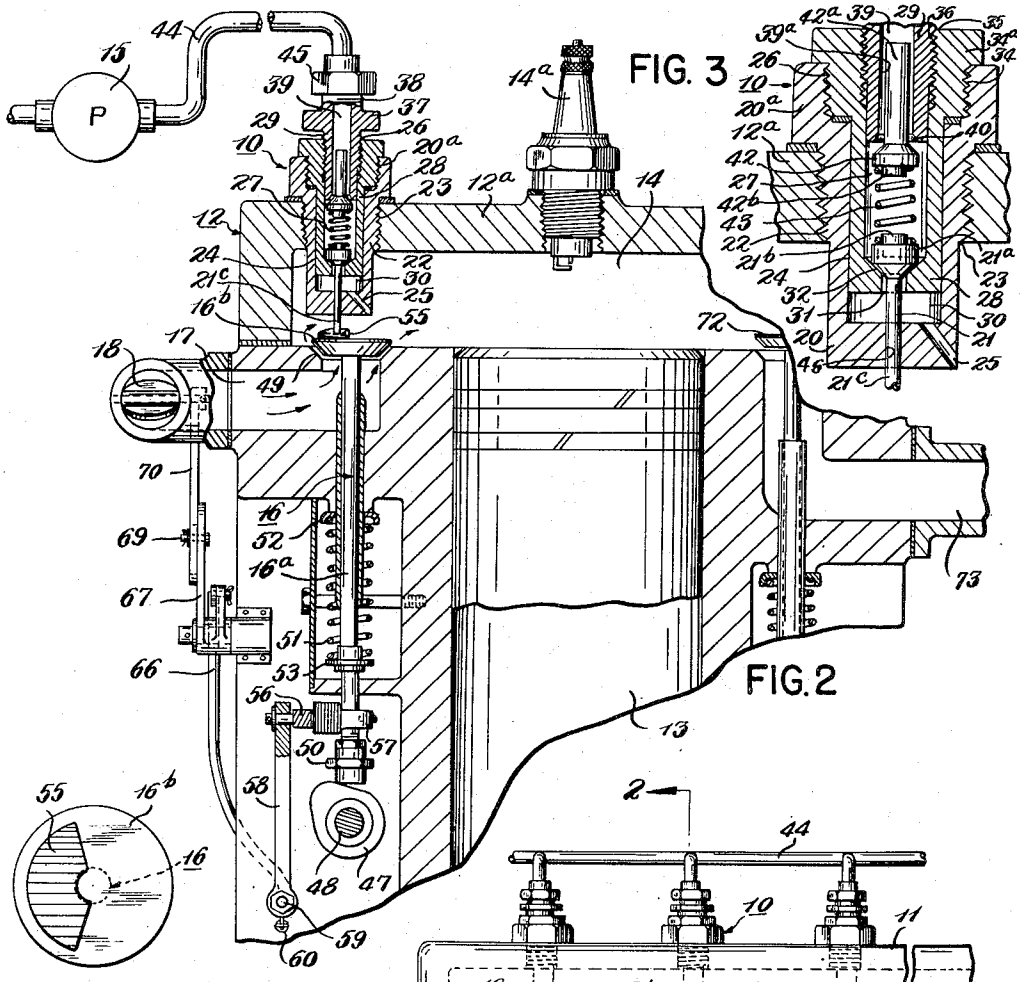


FIG. 5

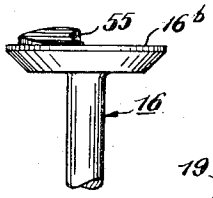


FIG. 4

FIG. 1

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VALVE-ACTUATED FUEL INJECTION APPARATUS

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This invention relates to fuel charge forming for internal combustion engines and, more particularly, to valve-actuated fuel injection apparatus for internal combustion engines.

Internal combustion engines may be generally divided into two classes according to the method employed in mixing the fuel and the air. In one class the fuel and air are mixed inside the cylinder, while in the second class the fuel and air are mixed before entry into the cylinder of the engine. In the latter class of engines, the fuel and air are mechanically mixed in a carburetor before entry into the engine cylinder, the fuel being fed to the carburetor by a pump designed to operate in conjunction with the carburetor. This method of mixing fuel has resulted in difficulties with both the fuel pump and the carburetor in obtaining proper cooperation and correct fuel mixtures at variable speeds.

It has been recognized heretofore that these pump and carburetor difficulties can be avoided by eliminating the carburetor and by using a high-pressure-delivery type of pump for supplying the gasoline, or other liquid fuel, directly to the cylinder through a fuel injection means. The present invention deals with the problem along this form of approach but eliminates the need for any costly distributor-type of fuel pump as has been needed heretofore.

As one of its objects, the present invention accordingly provides a valve-actuated fuel injector for an accelerator-controlled internal combustion engine which overcomes the difficulties associated with mixing the fuel and air in a carburetor before delivery into the engine cylinder and the accompanying problems of fuel pump cooperation with the carburetor, in that the injector is extremely simple and may be readily installed in the engine without resorting to special fuel pumps.

Another object is to provide an engine-valve-actuated fuel injector of the character mentioned in which the engine valve, preferably the intake valve, is provided with a cam means for actuating the fuel injector in response to two different types of motion imparted to the valve.

Still another object is to provide a novel engine-valve-actuated fuel injector having displacement means movable in a chamber relative to a self-closing fuel inlet valve for causing an injection discharge of fuel from such chamber substantially directly into the combustion space of the engine.

As a further object, this invention provides an air intake valve of the character described having a camming area of variable elevation to actuate a plunger for controlling a fuel injector through the presentation of the different elevations to the plunger for metering variable quantities of fuel passing into the cylinder.

Additionally, this invention provides novel fuel injection means for an engine operating on gasoline or the like as fuel, with spark plug ignition, comprising injector devices for the respective cylinders and supplied with fuel by a high-pressure-delivery pump and which injector devices are adapted to be opened in timed relation by

certain valves of the engine, the speed of the engine being controlled by varying the effectiveness of said certain valves on the injector devices associated therewith.

Other objects and advantages of this invention will be apparent from the following detailed description and the accompanying drawings forming a part of this specification, and in which:

Fig. 1 is a partial side elevation of a vehicle engine equipped with the fuel injection apparatus of this invention;

Fig. 2 is a partial transverse, vertical section taken through one of the cylinders of the engine substantially as indicated by section line 2—2 of Fig. 1;

Fig. 3 is an enlarged fragmentary, sectional view of the fuel injection apparatus as illustrated in Fig. 2;

Fig. 4 is a fragmentary, elevation view of the intake valve illustrated in Fig. 1 and constructed in accordance with the invention; and

Fig. 5 is a top plan view of the intake valve of Fig. 4.

The valve-actuated fuel injector **10** of this invention is shown in the accompanying drawings as applied to a four-cycle variable speed internal combustion engine **11** of the Otto heat-cycle type, although the invention is also applicable to internal combustion engines operating on other heat cycles. The engine **11** is a multiple-cylinder engine having cylinders **12** with reciprocating pistons **13** operable therein and with a compression chamber **14** above each piston. Each cylinder is provided with one of the injectors **10** and with a spark plug **14***a* arranged in the cylinder head **12***a*. The injectors **10** are supplied with a liquid fuel under pressure from a common high-pressure-delivery type of pump **15**.

Each of the cylinders is also provided with a movable engine valve **16**. The engine valve **16** is illustrated as the intake valve for controlling the air flow through the inlet port of an intake manifold **17** in conjunction with a throttle valve **18**. The positions of the intake valve **16** and the throttle valve **18** are adapted to be simultaneously controlled by a conventional accelerator **19** through suitable linkage operatively connected therebetween and further described hereinafter.

The fuel injector **10** comprises a plug-like injector body **20** projecting into the compression chamber **14**, and a movable control means **21** extending axially within the cylinder end of the injector body for contacting the intake valve **16**.

The injector body **20** has a threaded intermediate portion **22** by which it is mounted in a threaded opening **23** of the head **12***a* and defines an axial socket **24** having a closed inner end provided with one or more angularly disposed fuel outlet ports **25** for directing or spraying the fuel into the compression chamber **14**. The outer end of injector body **20** is in the form of a non-circular enlargement **20***a* extending above the cylinder head **12***a* and itself having an internally threaded end opening **26**.

An axially extending fuel receiving chamber **27** is defined in the injector **10** between an insert **28** and an adapter **29**. The insert **28** extends axially in the socket **24** and has its inner end spaced from the inner end wall of the body **20**, so as to define therewith a clearance space **30** which also serves as a fuel discharge chamber having the ports **25** leading therefrom. The inner end of the insert **28** has an axial passage **31** therein connecting the fuel receiving chamber **27** with the discharge chamber **30**. A valve seat **32** provided on the insert **28** at the bottom of the fuel chamber **27** surrounds the passage **31**.

The insert **28** is mounted in the body **20** by having an externally threaded head **34** engaged in the internally threaded outer end opening of the body. The head **34** has a non-circular portion **34***a* thereon and also has an internally threaded outer end opening **35** therein.

The adapter **29** is mounted in the insert **28** by having

an externally threaded portion 36 engaged in the internally threaded outer end opening 35 of the insert. The adapter is provided at its outer end with a non-circular portion 37 and a threaded nipple 38. A fuel inlet passage 39 extends through the adapter 29 into the fuel receiving chamber 27. The inner end of the adapter 29 is in the form of a sleeve having a valve seat 40 thereon and surrounding the inner end of the inlet passage 39.

The fuel receiving chamber 27 is arranged to contain the movable control means or fuel outlet valve 21 and a check valve 42 for controlling the passage of fuel into and out of this chamber. The check valve 42 is disposed in the fuel receiving chamber 27 to be seated on the valve seat 40 with its valve stem 42*a* extending into the fuel inlet passage 39 to define an annular fuel channel 39*a* around the stem 42*a*. The outlet valve 21 is constructed with a head enlargement 21*a* which acts as a displacement plunger in the fuel chamber 27, as is further described hereinafter.

The face of the check valve 42 is provided with a circular projection 42*b* to receive and seat the outer end of the fuel chamber spring 43. The inner end of the spring 43 is seated on a circular projection 21*b*, provided on the outer face of the fuel outlet valve 21 itself seated on the valve seat 32. The spring 43 normally holds the fuel outlet valve 21 and the check valve 42 in their closed positions but permits opening movement of the check valve by the delivery pressure of the pump 15 for passage of fuel into the chamber 27.

The fuel for the injector 10 may be derived from a supply tank and delivered to the injector at a high pressure by means of the pump 15. The fuel outlet of pump 15 is connected to the fuel line 44 having its opposite end connected to the injector 10. The fuel line 44 is secured to the outer end of the adapter 29 by means of a coupling 45 threaded onto the nipple 38.

The fuel outlet valve 21 has its stem 21*c* positioned in the axial passage 31 and extends through the clearance space 30 to slidably pass through an axial aperture 46 provided in the inner end of the injector body 20. The stem 21*c* is presented to the cylinder compression chamber 14 to actuate the valve 21, upon sufficient contacting force transmitted thereto by the engine valve 16 to overcome the pressure of spring 43, for metering the passage of fuel into the path of the air entering the compression chamber 14, as will be described more fully hereinafter.

The relative positions of the fuel outlet valve stem 21*c* and the engine valve 16 may be adjusted through the positioning of the non-circular portion 34*a* within the opening 26 provided for the injector body 20. The positioning of the stem 21*c* relative to the valve 16 determines the relative timing or actuation between it and the fuel outlet valve 21. Similarly, the non-circular portion 37 adjusts the position of the lower end of the adapter 29 on which the check valve 42 is seated.

In accordance with an important feature of the present invention, the actuation of the fuel outlet valve 21 through the action of the engine valve 16 is controlled by providing two different types of opening movements thereto: a linear movement and a rotary movement. The linear opening movement of the engine valve 16 is accomplished in a conventional manner through the utilization of a cam 47 illustrated as integral with its cam shaft 48. The cam shaft 48 is provided with a separate cam for actuating each of the engine valves in the same fashion as the valve 16 and in a predetermined timed relationship corresponding to the reciprocations of their respective pistons as is well known in the internal combustion art.

The cam 47 is illustrated in Fig. 2 as initially contacting the valve stem 16*a*, partially actuating same to lift the valve off its associated valve seat 49. The seat 49 is provided on the cylinder 12 in an opposed relation to the fuel injector 10. The valve 16 is actuated through the action of the cam 48 transmitted thereto by the

tappet 50 provided at the end of the valve stem 16*a*. The valve stem 16*a* is further provided with a valve spring 51 surrounding same intermediate its ends. The valve spring 51 is illustrated as having its top end seated in a cap-like spring seat 52 fixed to the engine frame and the opposite end is seated on the seating member 53 secured to the outer end of the valve stem 16*a*. The valve spring 51 is a compressive spring arranged to constantly urge the valve 16 towards its seat 49.

The actuation of the valve 16 in the aforementioned manner is arranged to open the valve to allow the passage of air from the manifold 17 into the compression chamber 14. The actuation of valve 16 is also effective to cause an engagement of the valve head 16*b*, and the cam 55 associated therewith, with the stem 21*c* which causes opening movement of the valve 21 relative to the valve seat 32. This opening movement of the valve 21 also causes a plunger action of the head enlargement 21*a* in the chamber 27 by which a quick initial injection of some of the fuel into the compression chamber 14 through the ports 25 is obtained for mixing of such injected fuel with the combustion air. During this plunger action, the check valve 42 is held closed by the spring 28 such that the displacement of fuel from the chamber 27 by the head enlargement 21*a* and/or the stem 21*c* must take place in a downward direction and produces a velocity discharge of fuel through the ports 25. This initial quick injection of fuel resulting from the plunger or displacement action is followed by a sustained fuel injection under the pressure of the delivery of the pump 15 as long as the valve 21 is held open. From the construction shown in the drawing, it will be seen that if the requirements of the engine are satisfied merely by the displacement action of the valve 21 in injecting fuel from the chamber 27 into the compression space 14, then the fuel pump 15 need not be a high-pressure-delivery pump but need be only a pump having a delivery pressure sufficient to cause opening of the check valve 42 and filling of the chamber 27 with fuel.

Upon the complete opening actuation of valve 16 a sufficient fuel charge is admitted to cause the engine 11 to attain a desired idling speed. To increase the engine speed, a larger fuel charge should be supplied to the compression chamber 14 and this is accomplished by providing for a greater extent of opening movement for the fuel outlet valve 21. This increased fuel charge results from the presentation of different portions of the cam 55 to the stem 21*b* of the fuel outlet valve 21.

The cam 55 in this instance is positioned off the center of the valve head 16*b* and approximately within a semicircular area thereon. The cam 55 is further arranged to provide an inclined plane-like profile or cam face for presenting variable elevations thereof upon rotating the valve 16 about the axis of its stem 16*a*. The stem 21*b* may be positioned for contacting a lower elevation provided on the cam 55 to provide a low or idling speed for the engine 11. The inclined profile provided for the cam 55 is effective to increase the opening movement of the valve 21 upon a counterclockwise rotation being applied thereto. It should be noted that the off-center position of the cam 55 or an off-center contact of the valve stem 21*b* with a camming surface on the valve head 16*b* is necessary in order that a variable opening movement may be imparted thereto.

The rotation of the engine valves 16 may be produced by cooperating toothed members, here shown as comprising a rack 56 and gear sectors 57, in response to the movements of the accelerator 19. The gear sector 57 is secured to each of the intake valves for the various engine cylinders 12 and positioned to constantly mesh with the reciprocating rack 56 to simultaneously rotate in unison therewith. The toothed portions of the sectors 57 are provided with sufficient area to maintain meshing engagement with the rack 56 upon the actuation of valve 16. The gear sector 57 for the valve stem 16*a* may be

secured to the stem intermediate the tappet **50** and the lower valve spring seat **53**. The rack **56** has the ends thereof suitably guided on the engine frame to allow the horizontal reciprocations thereof.

Secured adjacent the opposite end of the rack **56** is a motion transmitting arm **58** arranged transversely thereto for transmitting the horizontal reciprocating motion thereto. The opposite end of the arm **58** may be engaged by a horizontally positioned arm **59** and positioned substantially parallel to the rack **56**. The motion transmitting arm **58** may be further provided with a yieldable means for assuring the return of the rack **56** and thereby a return to or towards idling speed upon release of the accelerator **19**. In the drawing, a tension spring **60** is provided as the yieldable return means and is connected between the arm **58** and the engine frame.

The arm **59** imparts a horizontal motion to the motion transmitting arm **58** from an oscillating member or bell-crank lever **61** secured to an end of the arm **59**. The lever **61** is pivoted on a bracket **62** which is mounted on the engine or on the bottom of the vehicle floor board **63**. The lever **62** is connected to accelerator **19** by a link **64**. The actuating force of the accelerator **19** is transmitted by the link **64** to swing the lever **61** and the movements thereof are, in turn, serially transmitted, as described, to the gear sectors **57** to vary the actuation of the valve **21** to obtain an increased charge of fuel for increasing the engine speed.

Simultaneously with the actuation of the rack **56** and gear sectors **57**, the positions of the throttle valve **18** may be controlled to vary the air flowing into the intake manifold and, accordingly, the air presented to the compression chamber **14** by the opening of the valve **16**. The throttle valve **18** control is derived from the horizontal motions of the arm **59**. The arm **59** may have secured thereto an L-shaped member **66** which transmits a horizontal motion to a pair of suitable linkages arranged to control the vertical positioning of the throttle valve **18**. The one arm of the member **66** is arranged substantially horizontal to the arm **59** and is secured to a linking arm **67** intermediate the ends of the latter. The linking arm **67** is pivotally supported at one end to a bracket **68** fixed to the engine frame.

The member **66** is secured to the linking arm **67** to cause its free end to travel in an arcuate path. Adjacent the free end of the linking arm **67**, there is provided a linking pin **69** projecting from a face thereof and coupled to a horizontally positioned control arm **70**. The pin **69** is coupled to the control arm **70** by means of an elongated aperture provided to allow the pin to slide therein. The opposite end is pivotally mounted to the center of the throttle valve **18**. The arcuate movements of the linking arm **67** are coupled through the pin **69** traveling in the slot of the control arm **70** to the throttle valve **18**.

With the construction of the valve-actuated fuel injection apparatus described hereinabove in mind, it may be readily appreciated that the actuation of the accelerator **19** by the vehicle operator is effective to simultaneously control the fuel charge entering the cylinder compression chamber **14**. The motion of the accelerator **19** is translated to a rotary movement effective on the engine intake valve **16** and a linear movement to control the opening of the throttle valve **18**. The valve **16** is in this manner adapted to control and meter the fuel displaced from the fuel injector **10** into the path of the inrushing air and into the compression chamber **14** in response to the rotation and the actuation of the valve.

The thusly admitted charge is compressed by the advancing piston **13** and electrically ignited such as by a suitably timed spark from the spark plug **14** to thereby provided a power stroke for the piston. The exhaust charge is passed from the compression chamber **14** through an engine exhaust valve **72**. The exhaust valve **72** is also timed to open with respect to the reciprocations

of the piston **13** for allowing the charge to pass into the exhaust manifold **73**. A further advantage provided by the novel fuel injection apparatus of the present invention is the cooling effect normally present in the carburetor of the vehicle, which is hereby available to provide cooler running engine cylinders **12** as a result of the carburization within the cylinder.

Furthermore, it may be readily appreciated that the fuel may be injected directly into the engine cylinder by providing a suitable cam means fixed to the stem of the engine intake valve or the exhaust valve to control a valve in the fuel line, for example, and yet fall within the scope of the present invention. Also, the throttle valve may be eliminated from the intake manifold.

From the accompanying drawings and the foregoing description, it will accordingly be understood that the invention has provided novel apparatus for the injection of a fuel charge into an internal combustion engine without resorting to a separate carburetor to prepare a combustible mixture. The novel apparatus is of further advantage since it eliminates the need for special fuel pumps associated with a separate carburetor and the difficulties accompanying same. These salient advantages result from utilizing a novel valve for an internal combustion engine. The air intake valve head is provided with an inclined plane-like camming surface for presenting variable elevations to an outlet valve controlled fuel injector. The valve stem actuates the injector through varying positions of contact with the inclined camming surface to displace the fuel into the path of the inrushing air. The valve stem in this manner meters the passage of fuel from the fuel injector in response to the cam motion. The inclined cam elevations are presented to the fuel outlet valve stem through the rotation of the engine valve along with the normal actuation of the latter for providing an air passage into the cylinder compression chamber.

Although this novel valve actuated fuel injector apparatus has been illustrated and described herein to a somewhat detailed extent, it will be understood, of course, that the invention is not to be regarded as being limited correspondingly in scope but includes all changes and modifications coming within the terms of the claims hereof.

Having thus described my invention, I claim:

1. In an internal combustion engine, a cylinder, a piston operable therein, a fuel injector for the cylinder and having a movable control means for metering the passage of fuel therefrom, a movable engine valve for the cylinder, the engine valve having a cam means thereon to actuate said control means upon engagement therewith, means for actuating the engine valve, and means for rotating the engine valve to cause a different portion of the cam means to engage said control means for varying the extent of actuation of said control means.

2. In an internal combustion engine, a cylinder, a piston operable in the cylinder, a fuel injector including a movable fuel outlet valve presented to the cylinder, means for supplying fuel under pressure to the fuel injector, a movable engine valve for the cylinder, said injector being located in a substantially opposed relation to said engine valve, the engine valve having an off-center cam thereon for engaging and opening said fuel outlet valve, means for actuating the engine valve, and means for rotating the engine valve for changing the cam position relative to said fuel outlet valve to increase the opening movement of the latter.

3. An engine as defined in claim 2 in which said engine valve is of the type having a head, and in which said cam is formed integral with and located on the top of said head.

4. In an Otto heat-cycle type of internal combustion engine, a cylinder having a compression chamber, a piston operable in the cylinder, a fuel ignition means including a spark plug in the compression chamber, an intake valve for admitting air into the compression cham-

ber, said intake valve comprising a head carried by an actuating stem and a cam face integral with the valve head, a fuel injector for discharging fuel into the compression chamber and into the path of the air entering the chamber, the fuel injector having an outlet valve means including a second valve stem extending into the compression chamber for engagement by said cam face for metering the fuel flow into the chamber, means for delivering fuel under pressure to the fuel injector, means for actuating the intake valve, and means for rotating the intake valve substantially about the axis of its stem to cause a different portion of the cam means to engage said second valve stem to vary the extent of opening movement of said outlet valve means.

5. In an internal combustion engine, an engine body, a cylinder in said engine body and including a compression space, a piston operable in said cylinder, an engine valve associated with said cylinder, actuating means for said engine valve, a fuel injector mounted in said body and having a discharge end presented to said compression space, said injector having a fuel chamber provided with an outlet means communicating substantially directly with said compression space through said discharge end, means for supplying liquid fuel to said chamber, a displacement plunger movable in said chamber for causing fuel to be discharged therefrom through said outlet means, and plunger actuating means projecting from said discharge end and engageable by said engine valve for causing actuation of said plunger.

6. An engine as defined in claim 5 in which said outlet means includes a valve seat associated with a fuel delivery passage, and in which a valve member carried by said plunger is normally in engagement with said valve seat.

7. A fuel injector as defined in claim 5 in which said injector comprises relatively movable body sections, and means connecting said sections and providing for relative adjustment therebetween for varying the positioning of said plunger actuating means relative to said engine valve.

8. A fuel injector for an engine having a compression space and an engine valve movable therein comprising, a body structure containing a fuel chamber and having a fuel delivery end, said body structure being adapted for mounting in a wall of said compression space with said delivery end presented to said space, said delivery end having a delivery passage communicating substantially directly with said space and a valve seat associated with said passage, a fuel delivery valve movable in said body structure for controlling said passage and being normally in a closed position in engagement with said valve seat, and means projecting into said space from said body structure and engageable by said engine valve for causing opening movement of said fuel delivery valve.

9. A fuel injector as defined in claim 8 in which said fuel chamber has a fuel inlet passage controlled by an inwardly opening check valve, and in which said fuel delivery valve comprises a displacement plunger movable in said fuel chamber.

10. In an internal combustion engine, an accelerator, a plurality of cylinders, pistons operable in the cylinders, engine valves associated with said cylinders and each comprising a head and a stem, one certain engine valve of each cylinder having a cam on the head thereof in eccentric relation to the stem axis, fuel injectors for the respective cylinders located adjacent said certain engine valves and having fuel-delivery control means engageable and actuatable by the movable cams of said certain engine valves, means for supplying fuel under pressure to said injectors, said certain engine valves being rotatable about the axes of their stems for varying the effectiveness of said cams on said control means, and means responsive to the actuation of the accelerator for causing rotation of said certain engine valves.

11. An engine as defined in claim 10 in which the accelerator responsive means comprises a rack connected with the accelerator, and gear elements on the stems of said certain engine valves and engaged by said rack.

12. A fuel injector for an engine having a combustion space and a movable engine valve comprising, an injector body containing a fuel chamber and having a delivery end, said body being adapted for mounting in a wall of said combustion space at a point adjacent said engine valve with said delivery end presented to said space, said chamber having an inlet passage communicating therewith and a delivery passage means communicating substantially directly with said space through said delivery end, an inwardly opening check valve controlling said inlet passage, a discharge valve controlling said delivery passage means, spring means urging said check valve and said discharge valve toward closed position, displacement means associated with said discharge valve and being movable inwardly of said chamber for causing opening of said discharge valve and an injection displacement of fuel from said chamber into said space, and stem means projecting from said discharge end and engageable by said engine valve for actuating said discharge valve and said displacement means.

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